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A WEEKLY JOURNAL OF SCIENCE

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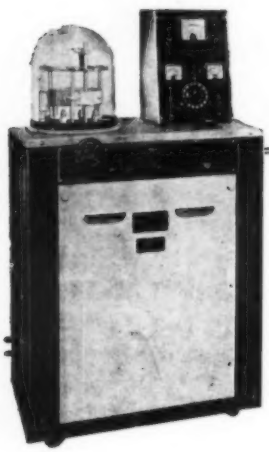

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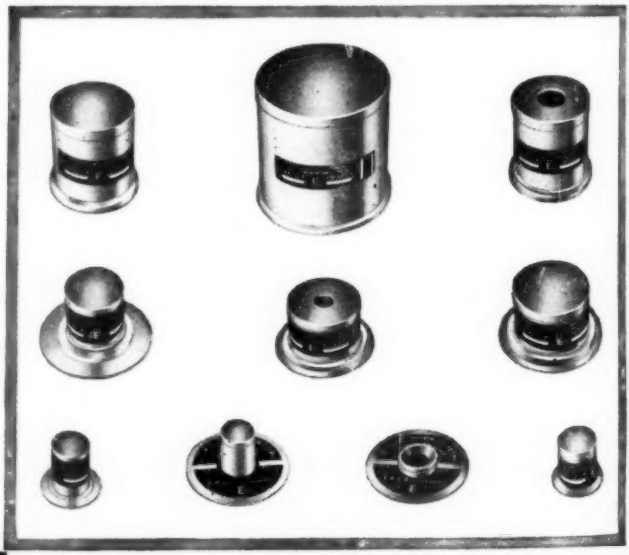

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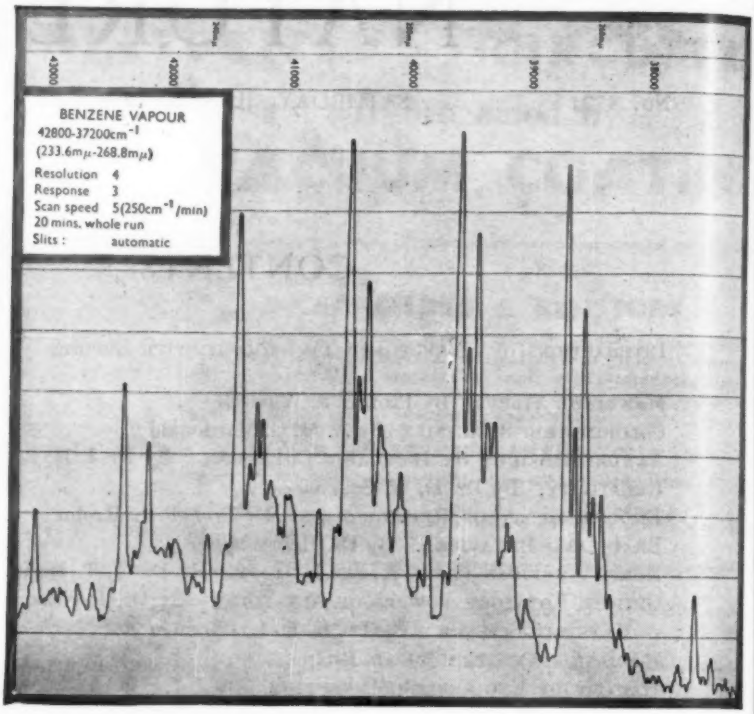

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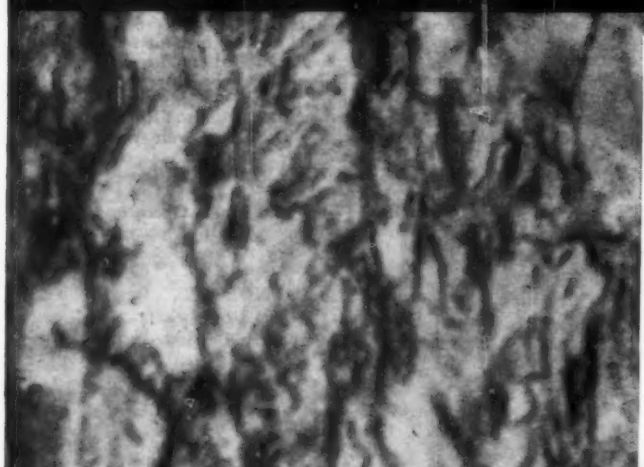

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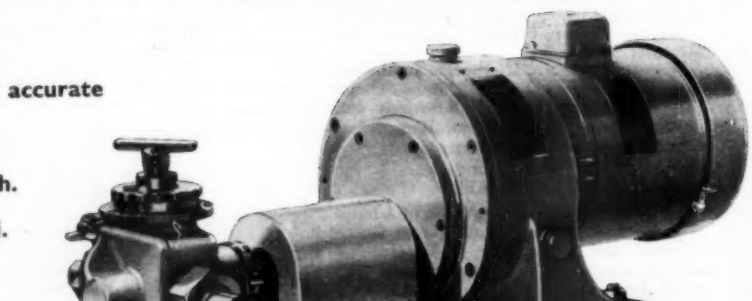

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INTERACTIONS OF SCIENCE AND TECHNOLOGY WITH SOCIETY

IN one of a series of lectures on the nineteen-sixties, printed in *The Listener* of March 24, Dr. Alex. Comfort discussed some of the factors which limit the applications of existing scientific knowledge, which determine, for example, whether or not at the end of this decade there will be no untreated cases of leprosy, yaws or malaria in the Commonwealth. The realization of such comparatively modest objectives, which are scientific possibilities and present no unusual difficulties, does not depend on fresh theoretical knowledge, lack of physical resources, or practical difficulties in the field. It depends rather on whether our vast technical resources are allocated to achieve such purposes by those in power, whether in democratic or in totalitarian society. Thus, from a completely different starting point, Dr. Comfort makes essentially the same point that was made by Sir Solly Zuckerman in his address last year on "Liberty in an Age of Science", and by Sir Eric Ashby in his oration at the Conference of European University Rectors and Vice-Chancellors.

Two other recent lectures develop very similar ideas. Mr. E. Le Q. Herbert, in his presidential address, "Chemistry, Industry and Society", to the Royal Institute of Chemistry on April 6, illustrated from one particular industry—the petroleum industry—the way in which society, science and technology interact to-day, and the limits which are set to what is technologically or socially possible. Sir Hugh Beaver, in the sixth Graham Clark Lecture to the Institutions of Civil Engineers, of Mechanical Engineers and of Electrical Engineers on March 3, assayed an even larger canvas. Under his title, "Engineering and Civilization", he reviewed the earlier five lectures as chapters in an attempt to discern the meaning of civilization and, putting these lectures into the perspective of the wide field of engineering thought, endeavour and achievement, he attempted to envisage the duty of the engineer in the new world that is so rapidly developing before us. Despite the different starting points and lines of approach, Mr. Herbert's and Sir Hugh Beaver's lectures have a good deal in common, and it is noteworthy that, like Dr. Comfort, they lay considerable stress on the importance of due attention to the problems of the under-developed territories, though incidentally Sir Hugh does not accept the view that the gap between the 'haves' and the 'have nots' is widening.

Sir Hugh Beaver starts with this fact that the population of the world is advancing at what by any calculation is a staggering rate: at the present rate of increase it will be 4,000 million in some 20–25 years time and 5,500 million by the end of the century. While the so-called under-developed countries are ceaselessly claiming the attention, service and money of the nations of Europe and North America, at the same time they are adamantly asserting their own authority and independence. The speed of advance which all these emerging countries envisage would more than tax all world resources, however mobilized, and their hopes are not in any way to be achieved by all the available money, however well used. Besides this, he pointed out, science and technology have brought us to the very edge of potential world destruction, and scientific research has brought us perhaps just to the threshold of the secret of the creation of living organisms.

The Western world is thus at a critical point in its history, and it is the basis of Sir Hugh's argument that engineers have a special responsibility because they have built this modern world of convenience and comfort, and all through the ages have not only been improving life but have also produced all the means and machines of destruction. In the first of the Graham Clark Lectures, Sir Harold Hartley reviewed the engineer's contribution to the conservation of natural resources; and without going into the picture Sir Harold Hartley displayed, Sir Hugh Beaver expresses the opinion that it is both incorrect and dangerously misleading to think that the basis of developed engineering is shortage of man-power. On the contrary, to-day we are proving that man-power is the basis of engineering, and Sir Hugh fears that we in Britain may eventually find ourselves out-distanced by our competitors simply because of their greater sources of man-power.

Sir Maurice Bowra, in the second lecture, dealing with the impact of engineering on society, suggested that without engineering civilization is impossible, and that China and Greece and Rome in turn lost their leadership in the world of their days because they treated engineering as of secondary importance. Sir Ewart Smith, in the fourth lecture, on "The Engineer and Management", claimed that the advance of science and its practical application through engineering and chemical technology had shown that mankind had the potential ability to achieve any standard of material well-being that may be desired; and whereas Sir Maurice Bowra had suggested that the engineers had gone wrong by assuming that improving the human lot just meant the greater exploitation of natural resources for the benefit of humanity, Sir Ewart Smith, more positively, but in the context of management, had added that our own civilization could continue successfully only if it achieved a balanced combination of the humanities and technology, based on both science and art. Though this criticism or suggestion is continually being made now, Sir Hugh Beaver pointed out that it was not always made: in the age of Leonardo de Vinci, the Elizabethan age or when the Royal Society was founded, this distinction between culture and art and science and engineering did not exist, and

the fathers of engineering as we know it in Britain were drawn from very varied origins to the adventure of practical and creative engineering.

Recalling Bacon's use of the Sphinx's riddle in the series of mythological fables that he called the 'Wisdom of the Ancients", Sir Hugh suggested that there are two kinds of riddles, one kind relating to the nature of things and the other relating to the nature of man, and that this perplexing, harassing problem may really be all or part of the explanation of the failure of some to distinguish between their duty to their country and their duty to mankind. Unless we can solve these problems arising in the impact of science on mankind, we must face the extinction of civilization and perhaps of mankind, and that is the problem particularly of scientists, technologists and engineers. What faces us here particularly is not what are the proper proportions of our man-power to be directed or attracted to this discipline or that, but how we are best to educate this and future generations in which inevitably the preponderance of educated output must be scientific and engineering.

This was the essential theme of Sir Ifor Evans's third Graham Clark Lecture, "The Place of Engineering in University Education"; but Sir Hugh ranged far outside that lecture in his survey of the way in which a balanced combination of the humanities with technology is to be achieved, referring particularly to Sir Eric Ashby's views as expressed in "Technology and the Academics", to that expressed by Huxley in 1867–68 in evidence to the Parliamentary Select Committee on Scientific Instruction, and to Sir Patrick Linstead's Hinchley Memorial Lecture in 1957. But it is not enough, Sir Hugh Beaver urged, for educationists to be giving thought to this problem of producing adequate citizens for the new world, who can deal with the problems of a scientific age, whether they approach them from the side of arts and the humanities or from the side of science and engineering. It is a matter for thought by engineers themselves, particularly as to how to produce the scientist and engineer as fully educated citizens of their country and of the world.

There is another aspect to be considered. Sir Maurice Bowra pointed out that no engineering had ever been revolutionary in the political sense, and engineering is not a political activity. Nevertheless, no one has the right to disclaim or 'opt out' of politics, least of all the engineer. Sir Hugh Beaver urged strongly that the great professional institutions should give continuous, and not just occasional, thought to these educational and political issues; that they should consider how far they could, in part at least, rectify omissions in the post-university life, and regard themselves not solely as platforms for technical discussion but also as providing the means of studying how engineers of the future could make a greater contribution to civilization.

Mr. Le Q. Herbert's address, particularly when he discusses the relations between the refinery and the community, shows how fully some responsible professional men recognize such responsibilities. When the graduate chemist or engineer carries Western culture into less-developed countries, said Mr. Herbert, urgent and ethical problems may arise, and we cannot leave them, with their wide implications, to solve themselves. He suggested that a great responsibility lay upon the scientist, the technologist and any other professional man when it came to considering how Western technologies could best assist the emergent or resurgent countries in achieving their national aims, and here above all the relation of professional ethics to industry and society must be acknowledged and used for good.

While Mr. Herbert clearly recognized that the professional societies have their part to play, he was also convinced that industry itself had its own responsibility for taking over the broadening process where the universities left off, and, by selecting, planning and helping the young scientist or technologist in his career, to develop this vital relation between industry and society. Professional institutions, the universities and industry have all their part to play in producing the type of man required; but it is as clear from these latest addresses as from that of Sir Solly Zuckerman that it is increasingly true that limits are set in other fields to what science or technology can do. Political strategy —and even the purpose behind the strategy—may be determined by decisions taken in quite unrelated fields, by the way in which the discovery of new ways of doing things transforms the things being done. As Sir Solly remarked, the element of the unknown in government increases with every step we are now taking to apply the fruits of science; the controversy that has recently arisen over the Government's policy with regard to the *Blue Streak* missile aptly illustrates the point. The urgency of this matter of a broad education can scarcely be over-stressed; it is important from the point of view of ensuring a stream of scientists and technologists and engineers, of administrators and statesmen alive to the human as well as to the technical issues involved in major political decisions, and equally important for securing public understanding and public acceptability of wise decisions made with full realization of the way they determine the future. It is to be hoped that the Minister for Science as well as professional associations of scientists and technologists will give due heed to Sir Hugh Beaver's appeal.

MAN-MADE FIBRES

Man-Made Textile Encyclopedia

Edited by J. J. Press. Pp. xxx+913. (New York: Textile Book Publishers, Inc.; London: Interscience Publishers, Ltd., 1959.) 200*s*.

WITH the possible exception of synthetic dyes, man-made fibres have been the most significant contribution of the scientist to the textile industry. These materials have greatly increased the scope of textile designers, and the public has been given a wider selection of interesting and attractive fabrics and garments often at low prices. Every industry

has benefited from the introduction of the new fibres for they have enabled basic operations such as transportation and purification to be carried out more effectively and more conveniently. The textile industry itself has also gained much, for the advent of the new materials has stimulated research and development in all branches of textile science and technology, not least in the manipulation of natural fibres. The offspring of the chemical and engineering industries, the man-made fibre industry is forward-looking and progressive, taking full advantage of the latest scientific and management techniques. Large sums of money are devoted to long-term research which has already resulted in the appearance of many new fibres and new methods of fibre production and processing. Even though the man-made fibre industry is comparatively young, a great mass of information covering all aspects of fibre production and manipulation has been published. Much of it, particularly that dealing with the technology of man-made fibres, is not readily accessible, and the publication of an encyclopædia such as the one under review is therefore welcome. The editor has been fortunate in securing the services of many authors, each an expert in his own field. The various sections of the book are therefore authoritative and informative.

The work is divided into twenty-two chapters and covers all aspects of man-made textiles, from the chemistry of the raw materials from which the fibres are made to methods for marketing the finished fabrics and manufacturing them into garments. Such a work could have been a rather uninteresting catalogue of equipment, machine settings and recipes, but this has been avoided. Even though a great deal of information is given (often in the form of well-constructed tables) the work is essentially a collection of readable essays welded together by careful arrangement into a complete whole. While the book will undoubtedly be used mainly as a reference book on general textile principles and practice, it is also valuable in revealing current trends. The opening chapters deal with the constitution and properties of the materials from which man-made fibres are made. Very appropriately this section is edited by Dr. Herman F. Mark, to whom the encyclopædia is dedicated. Accounts of fibre-manufacturing processes follow and include a short article on the production of superfine ($< 1\mu$ in diameter) thermoplastic fibres. The properties of man-made fibres and methods of fibre identification are then discussed in some detail. The technology and principles of converting fibres into yarns and finished cloth are dealt with in a general way, interesting sections being included on significant modern topics such as tow and high-bulk staple processing, non-woven textiles, and tufted materials. Cloth production and weaving are presented in relation to specific end-uses; for example, industrial and military fabrics, apparel fabrics, and household fabrics (floor coverings and upholstery fabrics). Some sixty pages are devoted to a most important discussion entitled "Textile Engineering Principles", which illustrates the modern scientific approach to the building of textile fabrics. In the sections on the dyeing, printing and finishing of fabrics, methods of handling most of the important man-made fibres are indicated, and the work is completed by accounts of topics such as knitted fabrics, garment manufacture, dry cleaning, commercial laundry practice, modern home washing methods, performance standards, statistics and marketing. A useful list of trade names of almost every man-made fibre in production is also given.

The discussion of such a wide range of topics necessitates a general treatment of each, but in spite of this a surprisingly large amount of valuable material has been included. The presentation is excellent, and a remarkable uniformity has been achieved throughout. The book is a valuable addition to the literature of textiles, not only because of its wide coverage but also because of the many unusual topics which are considered. Few will open this book without finding something to interest them. To prepare such a work and to maintain a consistently high level throughout is in itself a great achievement, and it is perhaps churlish to suggest omissions, as no doubt the editor had to make firm decisions to cut out much which he would have liked to include. He could, however, with advantage have introduced more references to original papers and specialized review articles. These would have added considerably to the usefulness of the volume. C. S. WHEWELL

COLORIMETRIC ANALYSIS

Colorimetric Determination of Traces of Metals

By Prof. E. B. Sandell. Third edition, revised and enlarged. (Chemical Analysis: a Series of Monographs on Analytical Chemistry and Its Applications, Vol. 3.) Pp. xxii+1032. (New York: Interscience Publishers, Inc.; London: Interscience Publishers, Ltd., 1959.) 185*s*.

A Handbook of Colorimetric Chemical Analytical Methods

Fifth edition. Pp. 360. (Salisbury: The Tintometer, Ltd., 1959.) 30*s*. net.

THE chemical analysis of traces of substances is now of great importance in areas as diverse as applied nuclear physics, soil science and medical chemistry. Colorimetric procedures are generally preferred for these determinations of trace elements. Although other, and often better, techniques are available, the expensive equipment required puts them outside the scope of all but highly specialized laboratories.

Prof. Sandell's book now achieves its third edition, which is about half as big again as the previous edition despite the removal of a good deal of the original material. The appearance of this volume is a tribute not only to the increased application of colorimetric methods but also to the great variety of new reagents and procedures which have been proposed in recent years. Prof. Sandell has not attempted to compete with the encyclopædic work of Snell and Snell. He has restricted himself to metals, and has chosen only a few procedures for the determination of each metal; his broad experience of chemical analysis and his common-sense approach ensure that the selection comprises the most useful and widely applicable procedures.

The text is divided into two parts: general aspects of inorganic colorimetric trace analysis, and procedures for the determination of traces of metals. Part 1 contains penetrating discussions on general trace analysis, on the separation and isolation of traces, on the application of colorimetry and spectrophotometry to their determination, and on colorimetric reagents. Colorimetry is regarded in its widest sense, fluorimetry, nephelometry and turbidi-

metry being included. In Part 2, which makes up two-thirds of the text, each metal is discussed under the headings of separation, methods of determination and, where the information is available, applications.

The sad fact that the development of new reagents has far outdistanced knowledge of their applications is repeatedly emphasized. Too often, new reagents are proposed without any reference to their behaviour in the presence of likely interfering elements and without reference to any advantage which the new procedure may have over earlier methods. The examination of the new reagents seems to be undertaken as an academic exercise and frequently an incomplete one at that. However, Prof. Sandell has picked his way with sure steps through the wide variety of methods available. Although the book is large, the subject has been treated with acuity, brevity and clarity, which are the more admirable when the multitudinous original sources are considered. The text is indispensable to all who are interested in colorimetry or trace analysis.

Little need be said concerning the second book, which contains the methods recommended by Tintometer Ltd. for use with their Lovibond range of apparatus. Contained in a loose-leaf binder, the sections deal with the apparatus, *p*H measurements, inorganic and organic chemical analysis, chemical pathological analysis, noxious vapours and miscellaneous methods. Any additions will be supplied free of charge for the next two years. The fifth edition has been enlarged and almost completely revised.

This collection of methods should prove useful in routine laboratories, for the procedures have been thoroughly checked by many workers and there should be no doubt of their reliability. The claims made for the convenience of the binding method would have been more impressive had the folder not come apart on preliminary handling.

A. M. G. Macdonald

ANNUAL REVIEWS ON INORGANIC CHEMISTRY

Progress in Inorganic Chemistry

Vol. 1. Edited by F. Albert Cotton. Pp. ix+566. (New York: Interscience Publishers, Inc.; London: Interscience Publishers, Ltd., 1959.) 109*s*.

THIS book consists of seven review articles considered to be of interest to inorganic chemists. This new series, appearing so soon after the first volume of "Advances in Inorganic and Radiochemistry" edited by Emeléus and Sharpe, must raise the question of their desirability, although it would appear that "Progress in Inorganic Chemistry" was first in conception. There is only one paper which is not in English, so that we may consider that the alternative places for publication of such articles would be *Chemical Reviews* or *Quarterly Reviews*, each catering for a rather different approach from the other. The excellent article by Roland Ward on mixed metal oxides, which is particularly notable for the clarity of its diagrams, seems to exemplify the type of paper for which "Progress in Inorganic Chemistry" was created. It would not fit easily into either of the existing journals for reviews.

However, this is not altogether true of the other papers in this volume. Becke-Goehring writes on nitrogen–sulphur compounds although there is a similar review on tetranitrogen tetrasulphur in *Quarterly Reviews*. "Interstitial Compounds of Graphite" by Hennig, which is more comprehensive than the corresponding article in "Advances in Inorganic and Radiochemistry", gives a good account of a subject in which little is definitely known. Too much inconclusive work is included. Again, "Metal-Ammonia Solutions" has recently appeared in *Quarterly Reviews* although the present review is more comprehensive.

The *Chemical Reviews* type of article is exemplified by that of Wilkinson and Cotton, who give an exceptionally good account of the rapidly expanding field of cyclopentadienyl and arene metal compounds. The only criticisms that can be made of this article are that the crystallographic nomenclature (on p. 20) is very inaccurate and that certain workers come in for excessive criticism. A somewhat similar paper by Malatesta on "Isocyanide Complexes of Metals" shows clearly the need for more structural work in a field in which problems abound. The crystallographic data cited in some cases are not the most recent, and the chemical nomenclature leaves much to be desired.

The only other paper is by George and McClure, on the effect of inner orbital splitting on the thermodynamic properties of transition metal compounds and co-ordination complexes. Reviews on this topic are usually either too elementary or go to the other extreme and assume at some stage that the reader is familiar with the work of Condon and Shortley. This comprehensive article, which includes a great deal of new material, goes some way towards the intermediate stage.

Altogether the reviews are satisfying, but with the tremendous accumulation of papers to be read through in a year any new source must prove its worth. The main task here lies with the editor in a skilful choice, preferably of topics which cannot suitably be treated in other places, or where a review is necessary to stimulate interest and bring in new research workers.

There are few misprints and errors, and the text is well produced.

I. R. Beattie

RELATIVITY

Theory of Relativity

By W. Pauli. Translated from the German by G. Field. Pp. xiv+241. (London and New York: Pergamon Press, 1958.) 35*s*. net.

The Theory of Space, Time and Gravitation

By V. Fock. Translated from the Russian by N. Kemmer. Pp. xviii+411. (London and New York: Pergamon Press, 1959.) 100*s*. net.

THE distressing thing about relativity is that the part of it which deals with gravitation—the general theory—is so isolated from the rest of physics. This is understandable, since gravitational forces are unimportant in atomic and nuclear physics, and non-Newtonian effects in astronomical systems are extremely small. Moreover, Einstein's idea of geometrizing gravitation has not yet been successfully extended to other fields of force. For these reasons, the general theory, for all its beauty and profundity, has until recently been rather neglected as a subject for research. This situation changed about five

years ago; since then there has been a tremendous surge of interest in general relativity. This interest is based mainly on the hope that, despite its quantitative unimportance for contemporary physics, gravitation and its geometrical description may be qualitatively important in the fundamental physics of the future.

In the light of this development the two books under review form a remarkable contrast. They are both written by famous physicists best known for their contributions to atomic theory and quantum mechanics, and they are both beautifully translated. But there the resemblance ends. For Pauli's book was written when he was a student of twenty-one, barely five years after the publication in 1916 of Einstein's definitive paper on general relativity, while Fock's is the product of a mature mind reflecting on a forty-year old theory. Yet Pauli's book reads as though the theory had already reached completion, while Fock's suggests that both its physical significance and its implications are not yet understood.

This contrast makes Pauli's book a simpler introduction to the subject, but correspondingly less stimulating to the research worker. It is better documented, more systematic in its presentation of standard material (in special as well as general relativity), and shows an astonishing breadth and mastery for so young an author and a subject. Greater glory was yet to come; but in none of his later writings did Pauli surpass in clarity, profundity or authority this juvenile performance.

To a modern eye some of his material lacks the interest which Pauli then attached to it, but this defect is balanced by the addition of twenty-three supplementary notes written in 1956 for this English edition. They contain an account of two of the main developments since 1921, namely, attempts by Einstein and others to unify gravitation and electromagnetism, and, in somewhat less detail, Friedmann's discovery of time-dependent cosmological solutions of Einstein's equations. There is a brief mention of the work of Einstein, Infeld and Hoffmann, and of Fock on the derivation of the equations of motion of material bodies from the field equations, but virtually nothing on such topics of recent interest as the initial-value problem, the quantization of the theory, and the associated problem of the existence and properties of gravitational radiation.

In contrast, it is the problems of deriving equations of motion and the properties of radiation which form the heart of Fock's book. His introduction to special and general relativity contains many interesting twists; but the main importance of his book lies in its detailed presentation of his own heroic calculations. He differs from Einstein, Infeld and Hoffmann in his systematic use of a stress tensor to describe matter, instead of regarding it as a singularity in the geometrical structure of space. He finds approximate solutions of Einstein's equations for both non-rotating and rotating masses, and obtains their post-Newtonian equations of motion and expressions for the gravitational potentials in the wave-zone. The calculations are extremely intricate, but are presented very clearly.

Fock performs his calculations in a particular co-ordinate system—the de Donder or harmonic system. If the space is Minkowskian at infinity, and if certain other conditions are satisfied, these co-ordinates are uniquely defined up to a Lorentz transformation. Fock believes that they are the natural analogue of the inertial systems of special relativity. In his view they do more than simplify certain calculations; they are of deep significance to the theory as a whole. This view is not shared by all students of relativity, most of whom believe that in general no particular significance can be attached to special co-ordinate systems. In their view all the physical implications of Einstein's theory can be expressed in terms of invariants which are completely independent of the choice of co-ordinate system. Only in special spaces (for example, those which satisfy simple boundary conditions at infinity, or which admit a group of motions) can a special co-ordinate system simplify calculations. In his book Fock defends his view in detail, and it is valuable to have this clear statement of his case. Whatever the final decision may be, his own calculations form a permanent addition to our knowledge of Einstein's theory.

D. W. SCIAMA

ENDOCRINOLOGY OF REPRODUCTION

Recent Progress in the Endocrinology of Reproduction

Proceedings of the Conference held in Syracuse, New York, June 9–12, 1958. Pp. xi+532. (New York: Academic Press, Inc.; London: Academic Press, Inc. (London), Ltd., 1959.) 12 dollars.

CONFERENCES and symposia on endocrinological subjects have been multiplying in recent years and it is becoming more and more common for the proceedings to be published *in extenso*. The practice has, however, several disadvantages. Some of the introductory general papers often provide nothing more than a refurbishing of material that has been published already or is in press. It is only when they give a critical and up-to-date account of a particular field which has not recently been covered that such papers are valuable. Other shorter contributions tend to report work in progress in an incomplete fashion, or because the editorial hand is often more gentle with invited papers, sometimes circumvent the full rigours of the refereeing system that submission to an appropriate scientific journal would entail. Finally, the printed proceedings are often long delayed and costly and the general result is further crowding, confusion and reduplication in an already overloaded literature.

Yet, with all these reservations one has to concede a warm, if reluctant, welcome to the published proceedings of another conference on the "Endocrinology of Reproduction", this time held at the New York State University Medical Center, Syracuse, during June 1958.

The arrangement of the programme was a logical and thorough one, beginning with a consideration of ovulation and passing via the hormonal balance in the normal cycle to fertilization, implantation, pregnancy and finally to parturition and lactation. The speakers on these topics were equally well chosen.

It is inevitable that among a collection of twenty-three papers, some should stand out as especially interesting to someone who wants to keep abreast of the current trends of opinion in reproductive physiology. Such are the papers by Chang on the fertilizing capacity of sperm, by Harris on the integrations between nervous and endocrine systems where they meet and overlap to control the process

of ovulation and by Folley and his colleagues on mammary growth and lactation. Others like that of Heller on the neurohypophysis during the œstrous cycle, pregnancy and lactation emphasize areas where research effort has been lacking and where fresh work, in this case on changes in water metabolism during the reproductive cycle, might be very profitable. The remaining papers are more in the nature of progress reports on work in hand. There are several on the levels of hormones to be found in the urine both during normal cycles and in pregnancy, and other topics include the capacity of the placenta to produce hormones, and the latest evidence about the status of relaxin as a hormone. A notable and pressing omission from the topics discussed at the meeting is the control of overall fertility patterns in relation to the world's population problem.

At its American price of 12 dollars this book is not perhaps an essential purchase for one's own bookshelves, but it is certainly worth reading.

P. L. Krohn

BRAIN AND BEHAVIOUR

The Central Nervous System and Behavior

Transactions of the Second Conference, February 22, 23, 24 and 25, 1959, Princeton, N.J. Edited by Mary A. B. Brazier. Pp. 358. (New York: Josiah Macy, Jr. Foundation, 1959.) 4.75 dollars.

THE verbatim recording and publication of papers and discussions presented at extended symposia is a characteristically American contribution to contemporary scientific communication. Well done, it conveys a remarkable atmosphere of actuality. Its informality is refreshing, and it permits the reader at some small remove of time to be taken to the brink of current experiment and speculation. Occasionally interruption of the text by interjection or argument is distracting; but more often it is both revealing and stimulating. The spirit of such meetings is epitomized by Dr. Fremont-Smith in his introduction to the present volume when he quotes the admonition "Don't speak when I'm interrupting".

This book presents the transactions of a conference held at Princeton in February 1959 and devoted mainly to the study of changes in animal behaviour induced by experimental cerebral lesions. The participation of a dynamically orientated psychiatrist (Douglas D. Bond) is revealing evidence of the mantle of scientific respectability worn by psychoanalysis in the United States, but still firmly denied to it in neurophysiological circles elsewhere. Dr. Bond's discussion of the possible relation between the behaviour which follows experimental hippocampal–amygdaloid lesions in the animal and that seen clinically in human anorexia nervosa is intriguing, as are some asides on the effect of a number of commonly used drugs such as amphetamine, meprobamate, and chlorpromazine, on animals subjected to similar cerebral lesions.

In other sections of the book Grastyan (Hungary) discusses electroencephalographic changes recorded in the hippocampus of the cat during the development of conditioned reflexes, and Bures (Czechoslovakia) the effect on behaviour of transient depression of cortical activity in the rat by the local application of chemical substances such as potassium chloride. Probably the chapter of greatest general interest is that by Rusinov (Moscow) on electroencephalographic work during the establishment of conditioned reflexes in man. Only here and in Dr. Galambos's (Washington) stimulating "summation" does the discussion briefly develop from technological detail to tentative philosophical generalization.

The book closes with an interesting account of Mary Brazier of a preceding colloquium on the electroencephalographic and higher nervous activity held in Moscow in October 1958. From this it is clear that the academic authorities of the U.S.S.R. have not been behindhand in sharing with the Americans the organization of similar high-level meetings for the exchange of knowledge and ideas in the neurological sciences.

It is depressing to note that although several speakers pay tribute to the contributions of Darwin, Hughlings Jackson and Sherrington to the scientific investigation of behaviour, references to current British work are almost non-existent, and that one British scientist attended the Moscow meeting, none the American. Fortunately the Macey and National Science Foundations, by making this excellent volume available at a relatively modest price, enable us to profit vicariously by the efforts of our more energetic colleagues.

Henry Miller

NORTH AMERICAN FRESH-WATER BIOLOGY

Fresh-Water Biology

By Henry Baldwin Ward and George Chandler Whipple. Second edition edited by Prof. W. T. Edmondson. Pp. xx+1248. (New York: John Wiley and Sons, Inc.; London: Chapman and Hall, Ltd., 1959.) 276*s*. net.

THIS new edition of an old favourite that appeared in 1918, virtually a new book, covers the fresh-water fauna and flora of North America except for free-swimming cercariæ, spiders and vertebrates. Forty-two groups are handled by fifty-one authors, two of whom are survivors from the first edition. In nearly half the groups the keys go down to species, and these tend to be the groups which have been neglected, in Europe at least, such as Porifera, Coelenterata, Gastrotricha and Tardigrada. The Crustacea are treated fully; but the keys to all the insect orders and to some other large groups go no further than genera. The introductions to the book and to each chapter give no more information about morphology and technique than is necessary for an understanding of the keys, and there is less of a general nature than in the first edition.

Illustrations are plentiful and good, the text is well laid out, and more than that it would be impertinent for anyone not closely acquainted with the American fauna to say. The question is: How useful will this book be in Britain? It covers the United States and Canada, an area that extends almost from the tropics to the Arctic, which means that it includes many more species than are found in Britain and in any European book, since all are on a national basis, "Faune de France", "Tierwelt Deutschlands", "Danmarks Fauna" and so on. There are, for example, 53 genera of Ephemeroptera in America, which is 5 more than the total number of British species; all but one of the 18 British genera are included in the 53. There are 89 species of Cladocera in the

Freshwater Biological Association's key, 121 in Ward and Whipple's and 60 are common, but this is a group well known for its cosmopolitan distribution and in many others the overlap is much less.

The references vary from chapter to chapter; sometimes there are none to European work, sometimes the main ones are included, particularly if they are written in English.

It is clear, then, that whoever uses the new "Ward and Whipple" will have to struggle with keys that are larger than is necessary for his purpose and which probably do not include the species before him. Moreover, there is much more on the European fauna than was available to his predecessor using the first edition. On the other hand, almost all freshwater animals and plants are dealt with between two covers and the book must therefore contain some organism allied to any specimen the identity of which is to be ascertained. This can be comforting to somebody who has prowled in vain around a scientific library searching for a key to the group to which a specimen is thought to belong, and even more comforting to somebody who has no scientific library to prowl around. A second point that will endear this new volume to a new generation is the full treatment of neglected groups. I believe, therefore, that the book will be found not to have lost its old appeal.

T. T. MACAN

OPTICAL ROTATORY POWERS OF ALKALOIDS

Tables of Constants and Numerical Data

11: Selected Constants: Optical Rotatory Power. 4: Alkaloids. By Prof. J.-P. Mathieu and Prof. M.-M. Janot. (Publication subsidized by the Member Countries of the International Commission of Tables of Constants and by the Centre National de la Recherche Scientifique.) Pp. v+211. (London and New York: Pergamon Press, 1959.) 160*s*. net.

THE present volume is the eleventh in the series of "Tables of Constants and Numerical Data", founded in 1909 by C. Marie, and it is the fourth in the series devoted to the optical rotatory powers of naturally occurring substances. The preceding volumes dealing with optical rotatory power have covered the steroids (1956), the triterpenoids (1958), and the amino-acids (1959), and all four have come under the general editorship of Prof. J.-P. Mathieu with the aid of specialists in the particular fields concerned. In this volume, devoted to the alkaloids, Prof. M.-M. Janot has collaborated with Prof. Mathieu, and Sir Robert Robinson has provided a foreword.

In view of the greater chemical diversity of the alkaloids the material covered in this volume is inevitably more heterogeneous than that considered in the preceding volumes, and the main function of the book is to collect together in one place the data scattered throughout the literature on optical rotation measurements made on alkaloids. The editors have been faced with the well-known problem of defining an alkaloid, and they have therefore based their criteria for inclusion on the considerations that the alkaloids form a group of organic compounds of vegetable origin, always containing nitrogen, possessing more or less pronounced basicity, yielding precipitates with certain 'general' reagents, and being endowed with remarkable pharmacological activities. It is realized, of course, that such a classification is somewhat arbitrary, and the editors have compiled a list of the known alkaloids, including minor alkaloids and many that have no action on polarized light, provided that an empirical formula has been assigned.

In the table of rotatory powers, the alkaloids and their salts are listed in alphabetical order by trivial names with molecular (or empirical) formulæ and melting points. Other column entries are molecular weight, and solvent, concentration, temperature, and wave-length for which the recorded specific rotations have been measured, and, finally, bibliographic references. The table, which has been compiled essentially from data found in original papers, occupies 166 pages, and the bibliographic references, given in a most convenient and compact form, occupy 23 pages, followed by an author index (10 pages) and a formula index (8 pages). The references (1809) span the interval between 1873 and mid-way through 1959, and their distribution over the years provides an interesting sidelight on activity in the field of alkaloid chemistry. Thus, the six decades from 1870 to 1929 provided only 19·3 per cent of the references, and the three decades since have provided respectively 18·4, 14·7, and no less than 47·7 per cent of the references. In fact, about one-third (32·8 per cent) of the bibliography relates to the last five and a half years covered, and it is obvious that, at this time of intense activity in the field of alkaloids, the present volume will be welcomed in laboratories where alkaloids are being studied.

It is a pleasure to note that a return has been made to a conventionally printed style, employing minute but very legible type, and the binding matches that of earlier volumes in the series.

J. WALKER

A MYTHICAL SCIENCE

The Masks of God

Primitive Mythology. By Joseph Campbell. Pp. viii+504. (London: Martin Secker and Warburg, Ltd., 1960.) 35*s*. net.

THE publishers claim that "The Masks of God" is "undoubtedly a landmark in its own field". Alas! Like so many landmarks it is also a folly.

The author's purpose is "the first sketch of a natural history of the gods and heroes, such as in its final form should include in its purview all divine beings. . . . For, as in the visible world of the vegetable and animal kingdoms, so also in the visionary world of the gods: there has been a history, an evolution, a series of mutations, governed by laws; and to show forth such laws is the proper aim of science" (p. 5). A new-born chick, says Dr. Campbell, will dart for cover when a hawk, or a model of a hawk, passes overhead—but not when the bird is a gull, duck, heron, or pigeon, or model of these latter. This kind of response to inherited, not taught, "innate releasing mechanisms", Dr. Campbell continues, is shared by human beings; and the biology, psychology, sociology and history of the sign stimuli which release these mechanisms of inheritance "constitute the field of our subject, the science of Comparative Mythology" (p. 41).

There is here a major distinction between what is common to all men and what is culturally determined;

there is also a distinction between part of the process of 'making' myths, and mythologies, which the author seems scarcely aware of. From such beginnings, without any analysis of the mechanisms of inheritance, mythologies are classified into those of the hunter, the planter, the ancient city dweller, and the peoples of prehistory; and an attempt is made to show, using the theories of the diffusionist and *Kulturkreis* schools—unconvincingly, I think—how such types of myths might have spread or diffused. The classification is useful: there are some interesting passages on the cuckoo, divine kings, the ritual love-death, shamanism, cave painting, a stickleback, and palæolithic and neolithic man, but the relations between the inherited image—imprinted on man's mind some 600,000 years ago, the poetic vision, cultural determinism, and culture change and diffusion remain—as one would expect—wholly obscure.

Diffusionist theory is necessary to this kind of construct, and some theories might provide models for what to-day is called 'acculturation'. Why cite Forbenius and Haeckel—who failed to construct such a model—and not Perry and Elliot Smith—who did? The seminal work of Hocart, Halbwachs, Van Gennep, Levi-Strauss, and Leenhardt is not mentioned. Indeed, these authors can offer little to one who, though some sort of Jungian, is determined to take his departure from Bastian without taking Neumann into account.

If there were a personal and imaginative synthesis the strange choice of authorities would not matter. For the central problems—how myths come to exist, penetration of the divine or mystical experience, the relation of myths to particular kinds of social structure and culture—are real and outstanding. But they will not yield to grandiose pretensions, second-hand psychology, muddled sociology, bad history, and an appalling confusion of biological and cultural levels.

K. O. L. Burridge

RADIATION AND THE BROAD BEAN

Radiation Biology of *Vicia faba* in Relation to the General Problem

By Dr. John Read. Pp. xxii+270. (Oxford: Blackwell Scientific Publications; Springfield, Ill.: Charles C. Thomas, 1959.) 45*s*. net.

THE roots of broad bean seedlings are stout and not very exacting in their requirements for good growth. The meristematic and differentiating zones are well demarcated, and squash preparations can easily be made to display the chromosomes in dividing cells of the root-tip. The chromosomes themselves are large and only twelve in number. The growth-rate of the roots can easily be measured by their increase in length. These are the main characteristics which have led many of those working on the effects of radiation on living systems to adopt the broad bean as their experimental material.

Dr. Read gives a systematic account of this work, restricting himself almost exclusively to investigations published after 1939. The reader is led in the early chapters through the effects of radiation on growth-rate, to a consideration of the inhibition of mitosis by radiation. It is the contention of the author that many effects of radiation on growth-rate stem from damage to the genetic material, and it is to an analysis of chromosome aberrations in relation to radiation that much of the book is devoted. The various conflicting theories as to the nature of chromosome aberrations are considered in detail in the light of all the available evidence as to the influence of the type of radiation, the dose-rate and the various environmental factors which affect the production of aberrations. Deoxyribonucleic acid synthesis after radiation is considered briefly, as is a comparison of radiation with radiomimetic chemicals in their effects on the bean root. Throughout, the results obtained with broad beans roots are compared with those obtained from other living systems. In a final chapter a valuable summary is made of the comparisons of this type which have been made in previous chapters. Dr. Read presents a formidable case for the utility of his superficially trivial experimental material. There is a bibliography of more than two hundred titles.

The presentation of the book is excellent, the type being large and clear and the text figures bold. Those intimately concerned with the biological effects of radiation will be grateful to Dr. Read for drawing together in such an accessible manner all the important information on *Vicia faba* and radiation.

HISTORY OF ENGINEERING INVENTION

Science as History

The Story of Man's Technological Progress from Steam Engine to Satellite. By Heinz Gartmann Translated from the German by Alan G. Readett. Pp. xvii+348+51 photographic illustrations. (London: Hodder and Stoughton, Ltd., 1960.) 25*s*. net.

"SCIENCE as History" has a more accurate subtitle "The Story of Man's Technological Progress from Steam Engine to Satellite". It is a popular account of engineering invention and development written around a number of the most important examples. The advance of the steam engine, motor-car and aeroplane, is followed by chapters on telecommunications, radio, radar, atomic physics, automation, and space exploration.

The author has not attempted a critical appraisal of the topics chosen—the work is in no way 'learned'; he has sought sensibly to recount some history in an interesting manner. In some chapters unnecessary detail clouds the overall pattern; for example, so many names appear in the steam engine section that the really important contributors never emerge. There is also a probably unavoidable national bias. When the United States, Britain, Europe and the U.S.S.R. are all working on similar problems, often under conditions of secrecy, it is exceedingly difficult to be just.

Some chapters lack balance; the space devoted to balloons and Zeppelins is twice that devoted to the immensely fertile period of aviation history from 1903 to date. Finally, the treatment of Dr. Eugen Sänger's lecture on relativistic mechanics applied to space flight is positively melodramatic.

In spite of these faults the book is immensely readable, beautifully produced, has a bibliography, and does display an appreciative understanding of the important and exciting developments selected. It deserves a wide audience.

J. L. Stollery

International Commission for Uniform Methods of Sugar Analysis

Report of the Proceedings of the Twelfth Session held at the National Bureau of Standards and at the Shoreham Hotel, Washington, D.C., U.S.A., from June 2nd to June 6th, 1958. Pp. vii+130. (Keston, Kent: International Commission for Uniform Methods of Sugar Analysis, Tate and Lyle Research Laboratories, New York: Sugar Research Foundation, Inc., 52 Wall Street, 1959.) 25*s.*; 3.50 dollars.

THE twelfth session of the International Commission for Uniform Methods of Sugar Analysis was held in Washington, D.C., in June 1958.

Its proceedings, which have now been published, contain detailed papers and discussions concerning some twenty-six problems which are primarily of special interest to those concerned with technical aspects of the sugar industry. The subjects for discussion included, among many others, such matters as the determination of sucrose and reducing sugars in molasses, the inorganic and organic constituents of raw sugars and sugar products, and factors causing deterioration of raw and refined sugars in storage and during transport. In each instance the problem had been referred to a group of experts from the various countries concerned. Their reports and recommendations for analytical methods are printed with full details of the experimental procedures. A verbatim account of the discussion which followed the presentation of each report is then given and finally the decisions of the Commission are recorded.

In some cases the referees' recommendations have been accepted only for guidance by analysts, no final decision being taken. It will be evident that this volume will be of interest mainly to professional analysts; but the methods described may be of great use also to investigators who have to deal with any aspects of carbohydrate chemistry which involve the separation and quantitative analysis of sugars.

E. L. HIRST

Precipitation Processes in Steels

Report of a Conference held in the University of Sheffield, 2–4 July, 1958, and organized by the Department of Metallurgy. (Special Report No. 64.) Pp. xiv+322. (London: Iron and Steel Institute, 1959.) 84*s.*

THIS account of a conference organized by the Department of Metallurgy of the University of Sheffield in July 1958 has been deemed of such interest by the Iron and Steel Institute as to justify its being published as a special report. With this opinion one must heartily concur. Twenty-one papers were contributed, grouped around the general themes of precipitation in ferritic and austenitic steels respectively, intergranular fracture and precipitation during creep. Such precipitation processes in alloy steels are obviously of the greatest practical importance and of very much theoretical interest; the time was ripe for such a discussion, and Prof. A. G. Quarrell, who appears to have initiated it, has clearly performed a most valuable service.

The quality of the contributions is high, a great deal of first-rate original work is included, and it is outside the bounds of possibility to review this in short space. One aspect of these papers, however, is outstandingly evident in the profuse use of electron-micrographs. After getting off to a slowish start in metallographic investigations, this technique has now established itself as an essential tool in this field. Where all is so good, it is quite unfair of a reviewer to single out for special mention the papers concerned with intergranular fracture in steel, but these four contributions, one from France and one from Sweden, go far to clarify a most important and elusive phenomenon.

This is a publication which it would not be easy to welcome in too high terms. F. C. THOMPSON

Health Physics Instrumentation

By John S. Handloser. (International Series of Monographs on Nuclear Energy. Division 5: Health Physics, Vol. 1.) Pp. x+182. (London and New York: Pergamon Press, 1959.) 42*s.* net.

THIS book is primarily designed for those familiar with the basic physics of radiation detection who now wish to make measurements for radiation control purposes.

The commercial instruments discussed and the laboratory practices described are those currently used in the United States. This does not detract from the value of the book to users in other countries, as the writer in the chapters on portable survey instruments, fixed monitors and neutron monitors gives the basic principles used, and then describes the way in which they have been applied and developed by different instrument designers. The writer thus describes briefly the range of techniques and instruments used for the measurement of neutrons, γ- and β-radiation and leaves the reader to judge which method is most suitable for his problem. In all chapters the brief details are supported by adequate references.

The techniques described cover the range of energies from tens of kilovolts to tens of megavolts. There is no discussion of the measurement of radiation from the highest-energy accelerators as the writer considers that health physics instrumentation in this field is still a research problem.

Chapters are also devoted to counting rooms and their equipment, calibration techniques and miscellaneous instrumentation, and an introduction which discusses units of measurement and acceptable limits of exposure.

The book is a useful introduction to health physics instrumentation for those entering the field and is also interesting reading for those concerned with radiation measurement for protection purposes.

B. S. SMITH

A Manual of Practical Vertebrate Morphology

By J. T. Saunders and S. M. Manton. Third edition. Pp. viii+272. (London: Oxford University Press, 1959.) 30*s.* net.

"THE aim of this Manual is to provide the student with an accurate description of the anatomy of certain vertebrate types which are dissected in an elementary course of Zoology." Since 1931, when the first edition appeared, it is clear that this aim has been well justified. In the second edition (1949) there was a welcome addition of six chapters dealing with the dissection of certain muscle systems in the rat, pigeon, frog and fishes. Until this third edition, however, there has been no guide to the general dissection of a mammal. The new chapter on the rat has been prepared by Dr. M. E. Brown and Dr. S. M. Manton. There is little that I need add, for 'Saunders and Manton' needs no introduction to classes studying vertebrate morphology.

N. B. MARSHALL

AGEING AND RADIATION

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STARTING with the pioneer work of Russ and Scott[1] and of Henshaw[2], it has repeatedly been suggested that whole-body irradiation of animals speeds up natural ageing[3–7]. Although highly specific long-term pathological effects can also be produced by irradiation[8], these may not arise in certain circumstances; for example, in animals undergoing chronic irradiation at rather low dose-rates or surviving the acute injury of single doses. Yet such animals die earlier than unirradiated controls, while the spectrum of pathological conditions present at death is about the same in both groups, that is, there is a non-specific shortening of life. Thus the evidence for a speeding up of ageing by radiation refers mainly to the late period of biological deterioration usually termed senescence (see review by Comfort[9]). Apart from fertility, physiological measures of ageing have not yet been studied as intensively in irradiated as in normal animals. Nevertheless, starting only from quantitative data on non-specific life-shortening in mice, I shall argue that there is some intrinsic process of biological ageing, enhanced by radiation, which operates from the start of life and is virtually complete by the time the changes of old age begin to appear. The argument has not been, and probably cannot be, established on a firm statistical basis from the data available. But because experiments in this field are difficult and because the establishment of some relation between natural ageing and that induced by radiation might afford a better insight into the nature of the fundamental mechanisms and lead to more fruitful experimental approaches, an attempt at an inductive generalization seems justifiable.

Theories of Ageing

In the context of ageing, two fundamental questions may be asked: Why does an individual die, and why do comparable individuals die at different times? The answers offered have fallen into two broad categories: (*a*) those which emphasize the element of randomness in mortality; (*b*) those which emphasize the genetically determinate element.

Random theories. Theories in this category, while recognizing that the outcome of the interaction between an environment and an individual depends on his genetic make-up, are concerned with the behaviour of a population of supposedly uniform individuals. Such theories attach considerable significance to the empirical age-specific death-rate, the so-called 'force of mortality', sometimes interpreted as the probability per unit time that any survivor will die in that time interval. For this to be true in an exact quantitative sense, all the individuals alive at a given instant would have to be identical, a qualification pointed out by Medawar[10], but not always sufficiently noted. The fact that the force of mortality in most populations increases with age beyond a certain point has been accepted as evidence of a progressive change in the population with age. Gompertz[11] noted that in human populations the logarithm of the age-specific death-rate increases approximately linearly with age from early maturity onwards, and so this quantity has been regarded as a general measure of physiological state, and its rate of change (approximately constant) as a measure of the rate of physiological ageing of the population, and even by tacit assumption, of each individual member thereof[12]. Sacher[13] has elaborated on these ideas in an elegant mathematical model which assumes that the individuals in the population are initially identical, but that due to random external stresses and physiological interactions there is a progressive drift and dispersion in the physiological states of these individuals. The death of an individual occurs when his physiological state transcends a certain limit. In this model the logarithm of the age-specific death-rate is directly proportional to the *mean* physiological state of the population at that age; the empirical Gompertz relation would thus seem to imply that the mean state changes linearly with time. The reality of the rate of physiological ageing so deduced will depend in any actual situation on the validity, among other things, of the assumption of initial identity of all individuals.

A progressive decline in physiological state or vitality is thus an essential feature of theories assuming random mortality, but a detailed causative mechanism for the decline itself is not usually specified.

Genetically determinate theories. These theories concentrate attention on the individual rather than the population and, in their quantitative aspects at least, on the component cells of the individual. The environment is scarcely considered explicitly, except as a more or less uniform influence; for a given environment the life-span of the individual is predetermined by the initial genetic endowment. In some theories, ageing is regarded as some process of change within cells themselves, possibly in their genetic apparatus[14–18]. These ideas are discussed further in the final section, but it is clear at once that the fate of the individual cannot be considered solely in terms of the fate of a component cell. In an animal, the cells are organized in a complex hierarchy of interacting anatomical and physiological systems. Thus while changes within cells may be the root cause of ageing and finally death, it may be inappropriate to consider the whole sequence of events solely in terms of the primary process. This idea is developed later on in this article.

A comprehensive general statement about the incidence of mortality in a group of individuals may be made in purely formal terms. An individual in a population is characterized by a particular value of some parameter τ, and the number of individuals in the class from τ to $(\tau + d\tau)$ is $N(\tau)d\tau$; there is a probability $p(\tau,t)dt$ that an individual in this class will die in the age interval from t to $(t + dt)$. The age-specific death-rate $\mu(T)$, at age T is then[19]:

$$\mu(T) = \frac{\int_0^\infty N(\tau) \cdot p(\tau,t) \cdot \exp\left[-\int_0^T p(\tau,t) \cdot dt\right] \cdot d\tau}{\int_0^\infty N(\tau) \cdot \exp\left[-\int_0^T p(\tau,t) \cdot dt\right] \cdot d\tau} \quad (1)$$

In the special case where all individuals are identical, the incidence of death as between individuals is random, and $\mu(T)$ reduces to $p(T)$. At the other extreme, where the death of a given individual occurs at a characteristic predetermined age, the parameter τ may be equated with the age at death of the individual, that is, $p(\tau,t) = 0$ for $t < \tau$ and $= \infty$ for $t \geqslant \tau$, so that $\mu(T)$ reduces to $N(T)/\int_T^\infty N(\tau).d\tau$. In this case the age-specific death-rate is merely an expression of the distribution of individual predetermined life-spans; the concept of a 'force of mortality' liable to strike down impartially and at random any member of a collection of identical individuals is then quite inappropriate. Further, the slope of the Gompertz plot, $\partial \ln \mu(T)/\partial T$, in this case need bear no direct relation whatever to a rate of real physiological ageing either in individuals or averaged over the population.

In an actual population, the factors of randomness and genetic variation are both likely to contribute to the dispersion of life-times, and either may predominate. For the human white female population of the United States at present, Szilard[16] suggests that most of the dispersion represented by the standard deviation of about 10 years is genetic dispersion, since the component due to randomness may be estimated from records of identical twins to amount to only 3 years. Even in non-identical twins, the average difference of life-times is about twice that in identical twins[20].

It is clear, however, that the genetic determination of life-time does not operate in a void, as it were, without reference to the environment. This is shown by the appreciable increase in average human life-times in economically developed countries in the past hundred years or so[21,22]. Much of this increase is due to a reduction of mortality in early and middle age; the change in old age, though real, is much less. The causes of death showing a reduction of incidence are mainly the infectious diseases, and might loosely be termed 'accidents' along with earthquake, famine, flood and the like in the sense that they are not intrinsic and inevitable, but kill certain individuals who might otherwise have gone on to reach old age. Some types of tumour also are not diseases of old age and may be included with the 'accidents'. This kind of division of deaths into 'accidents' and 'senescent' deaths is not new in actuarial analysis[21,23,24], and it acquires a fundamental, as well as empirical, significance in theories of ageing based on changes within cells. Broadly speaking, the risk of 'accidental' death is spread over the whole life-time, whereas 'senescent' deaths are clustered closely in old age, so defining a mean potential life-span.

Jones[25], on the other hand, attaches much greater importance to the 'accidents' and suggests that disease experience short of lethality is itself the cause of ageing, through an autocatalytic process of physiological impairment which is expressed as an impartial susceptibility to further disease. He suggests that the reduction in mortality in later life that has occurred in human populations has been caused by the reduction in diseases in early life. The correlation may not be causal, however, but merely arise from a common factor of improvement of environment[13]. The results of experiments on mice exposed to infection[26,27] designed to test Jones's hypothesis were equivocal[6]. Jones also cites the fact that in human populations the age-specific death-rates for various particular diseases and the rate from all causes show similar rates of increase with age, and regards this as further evidence for an increasing general susceptibility to disease. While this process may occur, particularly during senescence, it is possible that the similarity in rates arises, at least in part, because they all primarily reflect the same thing, namely, the genetic distribution of potential life-span.

A new model of ageing. My model of ageing, arrived at from evidence on irradiated and unirradiated mice summarized below, combines elements from all the foregoing theories. It assumes that there is a common process at work in natural and radiation-induced ageing which is fundamental, inevitable and irreversible. Other processes may also contribute to ageing, some peculiar to natural and some to radiation-induced ageing[5-8], and in particular circumstances any one of these may be the dominant factor, while some may be largely irrelevant by-products of ageing so far as survival is concerned, for example, the greying of hair. The model implies, however, that even if all these other factors could be obviated, an irreducible intrinsic process would remain, which may in fact predominate in certain circumstances for carefully kept populations of laboratory animals.

This intrinsic ageing occurs in two principal successive stages, which between them occupy the whole life-time. First, a stage of intracellular changes probably accompanied by intercellular reactions proceeds insidiously and without marked physiological impairment; this stage is termed 'induction'. When a certain level of inductive change is approached, the second stage of ageing sets in rather abruptly. It involves a different level of organization and consists in physiological interactions which proceed autonomously and autocatalytically when once initiated and which lead to rapid impairment culminating in death; this stage is termed 'development'.

It is an essential feature of the model that, after development is triggered off, further inductive change is superfluous; thus radiation during development has comparatively little effect. Formally, induction corresponds to a progressive destruction of homœostatic mechanisms, while development corresponds to senescence itself. Although the distinction between the two stages is one of degree rather than of kind, it is valid in practice because the level of physiological impairment is an extremely non-linear function of level of inductive change; Yockey[17] has pointed out the analogy with Shannon's channel capacity theorem in communication theory[28]. Physiological ageing therefore is mainly a phenomenon of senescence. The small physiological impairment during induction should not be regarded as the cause of ageing during development in any direct sense; both are effects of the underlying sub-physiological change. The false assumptions (*a*) that all the injury produced by whole-body irradiation of an animal or by the simple passage of time can and must be expressed as physiological injury, (*b*) that this injury is proportional to dose or time, have caused much confusion in the discussion and quantitative analysis both of reparable and irreparable injury by radiation and of natural ageing.

There will be very little element of randomness in the overall production of intracellular change during induction in multi-cellular organisms in a given

Table 1. Chronic Irradiation of *CBA* Mice from Early Maturity (~ 80 days) to Death (ref. 30 and unpublished work by Neary, G. J., Hulse, E. V., and Mole, R. H.)

Values of mean survival time (*MST*) and standard deviation of survival time (*SD*) in days, for males (*M*) and females (*F*) calculated for all animals in a group, and for last 70 per cent of group

			First experiment					Second experiment				
Dose-rate (rems/day)			0	0·23	0·46	1·02	11·0	0	2·46	3·48	16·1	27·2
All animals	*M*	*MST*	743	714	676	704	500	746	720	656	459	391
		SD	137	102	166	99	90	182	126	104	79	36
	F	*MST*	818	786	803	758	511	839	763	641	426	368
		SD	140	141	116	135	101	128	138	100	99	62
Last 70 per cent	*M*	*MST*	817	770	770	758	550	825	782	702	494	406
		SD	55	52	45	33	50	42	54	61	41	25
	F	*MST*	892	859	859	829	565	895	825	685	469	397
		SD	38	58	34	42	54	64	38	62	68	36

environment, but the effects of environmental stresses during development will be subject to random variation. The rate of development may depend more sensitively on individual characteristics than does the rate of induction, since it involves more complex levels of organization.

Intrinsic Ageing : Evidence from Irradiated Animals

Experiments at low dose-rates would seem to offer the best chance for detecting a non-specific speeding up of natural ageing by whole-body irradiation, because, for a given degree of life-shortening, repair mechanisms make the immediate physiological effects least under these conditions. Detailed data on mice irradiated continuously throughout life are available from two groups of workers. Lorenz and his colleagues at the National Cancer Institute in the United States[29] used gamma-rays to irradiate LAf_1 mice (first generation hybrids between two inbred strains, *C57L* females crossed with *A* males). The incidence of various pathological conditions at death was broadly similar in the irradiated and control animals, apart from some increase in tumours, particularly lymphomas. My colleagues and I (ref. 30, and Neary, G. J., Hulse, E. V., and Mole, R. H., unpublished work) irradiated *CBA* mice (an inbred strain) with fast neutrons or gamma rays. In our first experiment[30], the pathology at death was about the same in all groups and there was no clear-cut increase in overall incidence of tumours. In the second experiment the pathological findings have yet to be finally assessed (Hulse, E. V., and Mole, R. H., unpublished work). I have analysed the survival data from all these experiments on the working assumption that the principal effect of the radiation was a non-specific ageing.

The broad indications of data on non-specific life-shortening by radiation are that the *mean* shortening of life in a homogeneous group of animals increases with size of dose for a single exposure, or with size of *mean* accumulated dose for chronic exposure ; in either case, approximately proportional relations are found[4,31,32]. It has therefore usually been assumed that, with chronic irradiation continued until death, the shortening of life of an individual animal should depend on its particular accumulated dose ; thus a given dose-rate should produce the same proportional shortening of life in all the individuals. The cumulative mortality curve of an irradiated group would therefore be equivalent to that of the controls with the time axis contracted, and so the rate of ageing of the irradiated animals could be said to be accelerated compared with the controls ; the dispersion of life-times in an irradiated group would be reduced in proportion to the reduction of mean life-time. The LAf_1 mice of Lorenz *et al.*[29] conform fairly well to this simple picture, but our chronically irradiated *CBA* mice[30] do not show accelerated ageing in this sense. Instead, the cumulative mortality curve for an irradiated group corresponds to that of the controls with the time axis displaced, not contracted ; similarly, the Gompertz plots are displaced but the slopes are not increased by radiation. This result was described by the term 'premature ageing'[30], though 'premature senescence' is more explicit.

In terms of my model of ageing, chronic irradiation accelerates the basic sub-physiological process of ageing so that the duration of induction is shortened, but the ensuing development is almost unaffected by radiation at low dose-rates. It is assumed that *CBA* mice are sufficiently homogeneous genetically for the length of the natural induction period to be practically the same for all individuals, and that the dispersion of life-times arises chiefly from dispersion of length of development period, some of which at least is due to randomness in effects of environmental stress. When such mice are chronically irradiated, all individuals receive the same accumulated *effective* dose and all suffer the same shortening of the induction period. Development thus sets in prematurely, but at the same time for all, just as in the unirradiated animals. Thereafter, the probable course of events is the same for both groups ; for example, the shapes of the mortality curves, the slopes of the Gompertz plots and the dispersion of life-times will be identical apart from random variation. Attempts have been made to see whether these latter features, which I have found subjectively in the data, can be demonstrated or refuted on a firm basis of statistical significance, in order to decide between the alternative hypotheses of premature ageing (contraction of induction period only) and accelerated ageing (contraction of whole life-time). Some approximate arguments on the data of the first experiment alone supported premature ageing[30], but

Table 2. Chronic Irradiation of LAf_1 Mice from Early Maturity (~ 65 days) to Death (ref. 29)

Values of mean survival time (*MST*) and standard deviation of survival time (*SD*) in days for males and females combined, calculated for all animals in a group and for last 70 per cent of group

Dose-rate (rems/day)			0	0·11	1·1	2·2	4·4	8·8
All animals	*M* + *F*	*MST*	703	761	684	630	591	488
		SD	176	174	138	137	111	74
Last 70 per cent	*M* + *F*	*MST*	789	846	756	702	645	546
		SD	133	90	80	84	73	56

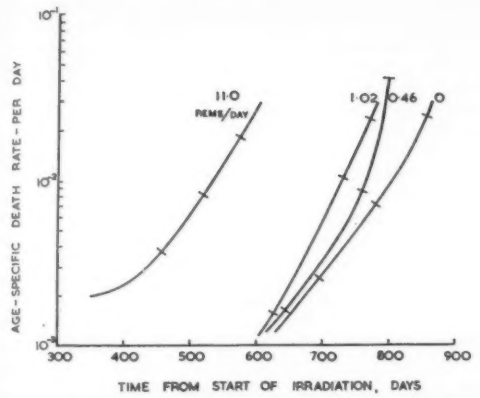

Fig. 1. Gompertz plots, *CBA* mice, males (ref. 30). The three bars on each plot in Figs. 1–5 correspond to 30, 50 and 80 per cent cumulative mortality

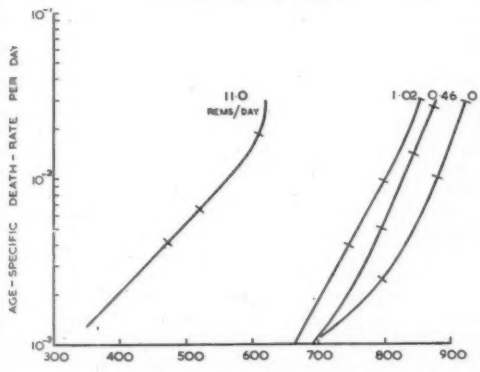

Fig. 2. Gompertz plots, *CBA* mice, females (ref. 30)

a more detailed examination of the data of both experiments suggests that they do not contradict either hypothesis at the 5 per cent level of significance (Neary, G. J., and Westgarth, D. R., unpublished work); or that neither hypothesis fits[33], though premature ageing is closer than accelerated ageing (Wise, M. E., unpublished work). Here, I shall merely present a summary of the data on mean survival-time and standard deviation of survival-time, together with graphs of the Gompertz plots with values of slope and doubling time. Some obvious differences between the *CBA* and LAf_1 mice are then apparent.

The dose-rate of all irradiated *CBA* groups has been expressed in rems/day, using the conversion factors 1 rad of cobalt-60 gamma radiation = 1 rem and 1 rad of our fast neutrons = 12 rems (determined from the intercomparison of life-shortening in our neutron and gamma groups (Neary, G. J., Hulse, E. V., and Mole, R. H., unpublished work). Doses for the LAf_1 mice were given in roentgens and the small difference for radium gamma-rays between rem and roentgen (= 0·98 rem) has been ignored here.

Certain facts stand out when Tables 1 and 2 are compared. First, the trend towards smaller standard deviation with increasing dose-rate and decreasing mean survival-time is much less marked for the *CBA* than for the LAf_1 mice. This point is shown more clearly by taking only the last 70 per cent of mice dying in a group, this being a very rough method of separating the mainly 'senescent' deaths from the mainly 'accidental' deaths (which incidentally may be shown to be far less affected by radiation in time of occurrence—data on first 30 per cent to die). Since for the LAf_1 mice the proportional reduction in standard deviation for a given dose-rate is at least as great as that in mean survival-time, it appears that, unlike the *CBA* mice, there is a considerable dispersion of induction-times, which is the main component in dispersion of total life-time. This conclusion is reinforced by the fact that the standard deviations for the LAf_1 mice are considerably larger than for the *CBA* mice, though their mean survival-times are somewhat smaller. Thus for life-time irradiation of LAf_1 mice at a given dose-rate, there is a considerable dispersion in accumulated effective dose. In fact, the individual effective doses are nearly proportional to the individual life-times, because, as shown below, induction comprises the greater part of the life-time; and so LAf_1 mice display a misleading appearance of simple accelerated ageing by radiation, that is, an apparent contraction of the whole life-time.

An examination of the Gompertz plots supports these conclusions and leads to some additional ones. From Figs. 1–5 and Tables 3 and 4 (refs. 13, 34) it may be seen (*a*) the Gompertz plots are not very linear; (*b*) with increase of dose-rate there is a trend towards steeper plots for the LAf_1, but not for the *CBA* mice up to ~ 15 rems/day; (*c*) for the unirradiated *CBA* mice the death-rates are generally greater and the Gompertz slopes steeper than for the unirradiated LAf_1 mice at a given level of cumulative mortality. If the usual interpretation of Gompertz slope as rate of ageing were accepted, these data would mean that irradiated *CBA* mice were ageing at the same rate as the controls, though their survival-time was nearly halved; and that the control *CBA* mice were ageing about five times faster than the control LAf_1 mice though they lived rather longer. The Gompertz plots for the two kinds of mice must therefore cross at some earlier time; and if each plot were extrapolated back linearly to the beginning, we should have the unlikely result that the initial death-rate of the LAf_1 mice would be some 10^8 times that of the *CBA* mice. In fact the plots do not continue straight very far backwards, and the slopes are smaller at earlier times.

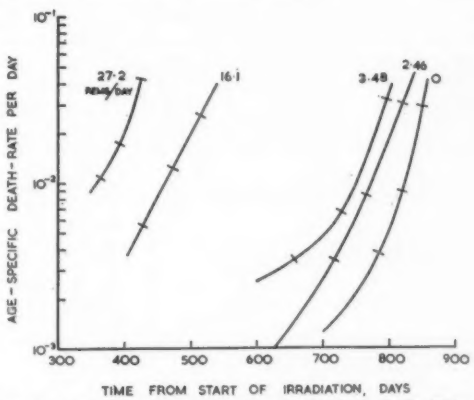

Fig. 3. Gompertz plots, *CBA* mice, males (Neary, G. J., Hulse, E. V., and Mole, R. H., unpublished work)

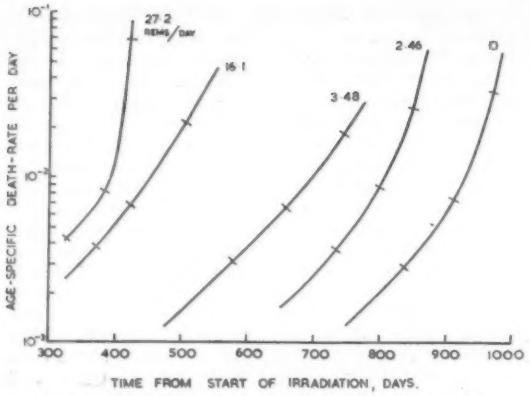

Fig. 4. Gompertz plots, *CBA* mice, females (Neary, G. J., Hulse, E. V., and Mole, R. H., unpublished work)

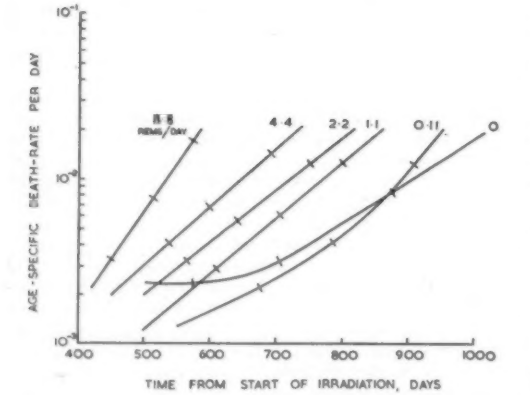

Fig. 5. Gompertz plots, LAf_1 mice, males and females combined (ref. 29)

These results provide no evidence for a process of physiological ageing proceeding at a roughly constant rate throughout most of adult life, as commonly postulated. In so far as the Gompertz slope measures rate of physiological ageing at all, this rate is much less before than during senescence, and the apparent rate before senescence is largely an artefact of the analysis due to 'accidents'. Moreover, it may be the exception rather than the rule for the innate variation between individuals to be small enough not to obscure such evidence of physiological ageing as might ideally be obtained from the dependence of death-rate on age in a uniform group. It is clear that the change in the Gompertz slope is unlikely to be a reliable index of ageing induced by radiation. When applied to the data on life-shortening in the LAf_1 mice, Failla and McClement[25] found it necessary to use the Gompertz relation in a formal sense only, as a mathematical transformation of basic data on mean survival-time. In *CBA* mice the Gompertz slope mainly reflects the rate of senescence, which is practically unchanged by life-time irradiation at low dose-rates; it tells nothing of the acceleration of the primary process of ageing during induction, which is responsible for the premature onset of senescence and for shortening of life.

The apparently much greater dispersion of induction times in the LAf_1 mice than in the *CBA* mice is unlikely to be due to an effect of differences in environmental conditions in the two laboratories, because afterwards a similar behaviour of the LAf_1 breed was found elsewhere[26,27]. Nor can the difference between the LAf_1 mice of Lorenz *et al.*[29] and our *CBA* mice be attributed to the pooling of survival data for LAf_1 males and females, since in the later work[26,27] the data for males and females are given separately. It may be that the considerable incidence of lymphomas in the control animals and its appreciable increase in the irradiated groups (up to 65 per cent in the females at 8·8 rems/day) is an indication that a particular pathological process rather than a non-specific ageing is responsible for the death of a good proportion of the mice. Brues and Sacher[28] observed an increase in the slope of the Gompertz plot for chronically irradiated female *CF* No. 1 mice, a breed usually showing a high incidence of mammary tumours. Alternatively, it is possible that there is a real dispersion of induction periods for non-specific ageing between individuals due to genetic causes, even though LAf_1 mice, being a first-generation cross between two inbred strains, would be expected to be genetically uniform. If the parent strains were absolutely uniform, then the f_1 cross would also be uniform; but if there were some variation in each parent strain, these variations would be combined multiplicatively in the f_1 cross. The possibility of a genetically determined difference in dispersion of induction times between LAf_1 and *CBA* mice thus involves the comparative genetic uniformity of the parent strains *C57L* and *A* and the *CBA* strain, and the influence of the factor of hybrid vigour.

Dose-response and the derivation of values for times of induction and development. I assume that a low dose-rate of radiation, r rems/day, produces the basic intracellular changes responsible for ageing, at a rate λr times the natural rate at any instant; the total instantaneous rate is thus multiplied by a factor $(1 + \lambda r)$. The accumulation of changed cells would be determined by the dynamics of the changed and normal cell populations; if there were competition between these cells, an alteration in the time required to attain a critical level of changed cells might depend in a complicated

Table 3. Gompertz Analysis, *CBA* Mice (ref. 30 and unpublished work by Neary, G. J., Hulse, E. V., and Mole, R. H.)

		First experiment					Second experiment				
Dose-rate (rems/day)		0	0·23	0·46	1·02	11·0	0	2·46	3·48	16·1	27·2
Slope per 100 days	*M*	1·4	1·4	1·8	2·1	1·5	3·4	2·3	1·7	1·8	2·0
	F	2·2	1·6	2·3	1·7	1·2	1·9	1·8	1·7	1·3	4·0
	Mean	1·8	1·5	2·0	1·9	1·3	2·7	2·0	1·7	1·5	3·0
Doubling time (days)	*M*	51	49	38	34	47	20	31	40	39	35
	F	32	44	30	42	57	37	39	42	53	18
	Mean	42	46	34	38	52	28	35	41	46	26

Table 4. GOMPERTZ ANALYSIS, LAf_1 MICE (ref. 29)

Dose-rate (rems/day)		0	0·11	1·1	2·2	4·4	8·8
Slope per 100 days	*	0·38	0·66	0·74	0·79	0·91	1·0
	†	0·53	0·72	0·79	0·93	1·0	1·2
	‡	0·53	0·79	0·79	0·73	0·83	1·3
Doubling time (days)	*	166	106	95	88	77	67
	†	120	97	88	75	70	56
	‡	131	89	89	95	84	52

* Analysed by Sacher (ref. 13).
† Analysed by Berlin and Dimaggio (ref. 34).
‡ Analysed in this article.

way on an alteration in their rate of production[14]. Some model of the intercellular relationship is necessary in order to derive values for times of induction and development from the empirical data on life-shortening. In a number of possible models, an increase in the rate of production of changed cells from normal cells will result in a simple inverse contraction of the time required for the accumulation of a given level of changed cells. Since the critical level is assumed to be the same in irradiated and control animals at the ends of the respective induction periods, durations I and I_0, we have:

$$(1 + \lambda r)I = I_0$$

whence

$$(I_0 - I) = \lambda r I \qquad (2)$$

that is, the shortening of induction period $(I_0 - I)$ is proportional to the dose accumulated in the induction period, rI, the accumulated effective dose. The duration of the development period, D, is unaffected by radiation at low dose-rates and therefore the shortening $(S_0 - S)$ of life-time, S, is equal to $(I_0 - I)$, and so it too is proportional to accumulated effective dose. Time and radiation-dose are thus equivalent factors in ageing, and in this sense the dose-response is linear, although the proportion of cells changed is not necessarily a linear function of time or dose and the resulting physiological injury is probably a very non-linear function of these quantities.

The derivation of values for times of induction and development and the constant λ on the basis of the linear relation (2) for chronic irradiation is straightforward in principle, but with our data the accuracy of determination of development time is very low. Since by hypothesis $(I_0 - I) = (S_0 - S)$, we have $(S_0 - S)/r = \lambda I = \lambda(S - D)$; or, more generally, when irradiation starts at age T and continues until death:

$$(S_0 - S)/r = \lambda(S - T - D) \qquad (3)$$

A plot of mean values of $(S_0 - S)/r$ against mean values of time of survival $(S - T)$, for groups of animals at different dose-rates, r, should thus be a straight line with slope λ and intercept on the abscissa axis D, the mean development time. The data used in Figs. 6 and 7 are for the last 70 per cent of animals in a group to die, so as to reduce the influence of 'accidental' deaths. The values of D for males and females so obtained are in each case about 180 days. In this analysis any error of mean shortening of life or disturbance through side-effects is greatly exaggerated for the low dose-rate groups because of the divisor r in equation (3). Errors in r, the biologically effective dose-rate expressed in rems/day, can also seriously distort the graphs, and since fast neutrons and gamma-radiation were used, the values of r depend on the relative biological efficiency factor for the fast neutrons which the experiments were primarily designed to determine. It is thus not surprising that the spread of points is large in Figs. 6 and 7. If the same treatment is applied to the data on LAf_1 mice of Lorenz *et al.*[29] (males and females not given separately) or of Sacher, Grahn and Gurian[36] (survival data of last 70 per cent not given separately), the spread is too great to permit of any estimate of D. These difficulties should be reduced by using a fixed dose-rate and varying the age at which irradiation starts (Neary, G. J., and Mole, R. H., unpublished work). The estimate of $D = 180$ days agrees roughly with recent observations that for $BALB/c$ mice which received 500 r. at age 435 days, the age-specific death-rate became significantly greater than in controls only at age 575 days (average for males and females), that is, 160 days before the median life-span of the irradiated animals[39].

The best estimate of λ from our present data may be obtained from equation (2), which for animals starting irradiation at age T, may be written:

$$(S_0 - S) = \lambda r(S - T - D) \qquad (4)$$

By using the value of D obtained from Figs. 6 and 7, the mean accumulated effective doses, $r(S - T - D)$ for the groups at the different dose-rates may be calculated and used to make graphs of life-shortening against dose (Figs. 8 and 9). The values of λ given by the slopes are 0·065 day/rem for males and 0·086 day/rem for females, agreeing with other data on the life-shortening efficiency of chronic irradiation of mice[4,31,32].

Nature of the Induction Process and the Problem of Extrapolation between Species

The linear form of the dose-response for non-specific life-shortening by radiation at low dose-rates is consistent with a cumulative injury due to irreversible

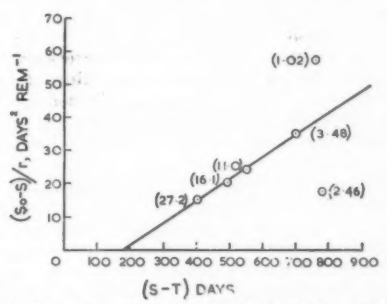

Fig. 6. *CBA* mice, males. Numbers in brackets are daily dose rates. The intercept is the mean development time (see equation 3)

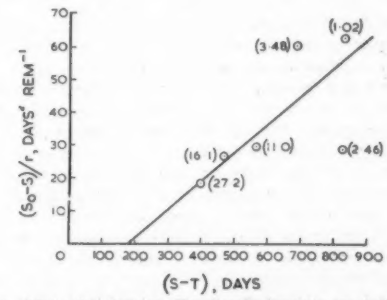

Fig. 7. *CBA* mice, females. Numbers in brackets are daily dose-rates. The intercept is the mean development time (see equation 3)

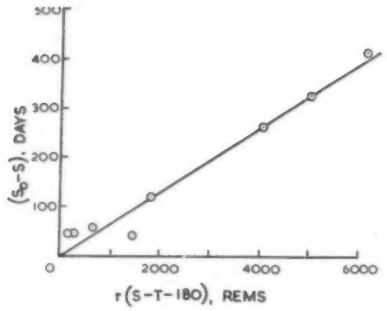

Fig. 8. *CBA* mice, males. Life-shortening against mean accumulated effective dose (see equation 4)

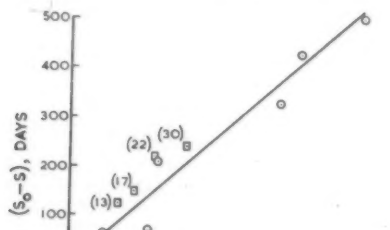

Fig. 9. *CBA* mice, females. Life-shortening against mean accumulated effective dose (see equation 4)
○, life-time irradiation; ⊡, irradiation for limited periods of weeks shown in brackets

changes in cells. This is in marked contrast with the short-term physiological injury, for which there is a very non-linear dose-response and a recovery process with a time-scale measured in days or weeks[5]. The linear relation implies that a given increment of dose would have the same effect at any time up to the completion of induction. This is confirmed approximately in the similar degrees of life-shortening produced by single, fractionated and life-time doses of fast neutrons[32,40]. Some results on our female *CBA* mice given chronic irradiation for limited periods[30] have been included in Fig. 9, and they agree fairly well with the results for life-time irradiation, considering that the animals in most of the limited irradiation groups, unlike those in the life-time groups, were used for breeding experiments. The linearity with life-time irradiation, however, may result from a precarious balance in the intercellular dynamics; if so, the balance might well be upset by a sudden fall in production of changed cells on cessation of radiation. The linearity and independence of age inferred from life-time irradiation and single-dose data could therefore not necessarily be expected for other regimes of irradiation in which, moreover, specific disease processes might assume greater importance.

Although there is approximate independence of the timing of the dose for fast neutrons, this is not the case with *X*- or gamma-radiation, single doses of which are some three times as efficient as doses spread over the whole life-time, though in each case the dose-response is approximately linear[4,31,32]. If the greater life-shortening efficiency of single doses is attributed to a greater efficiency of production of the primary intracellular change, and if the dose-response is indeed linear, then it is difficult to equate the intracellular change with chromosome structural damage[13,14], because the only types of such damage which are produced more efficiently by single doses than by protracted doses have a considerable square-law component in their dose-response[41]. These arise from the interaction of two independently produced sites of potential damage, each with a limited life-time, usually of the order of an hour. The linearity of the life-shortening dose-response for small single doses is somewhat uncertain owing to the low accuracy of the data. It has been shown, however, that the life-shortening effect of a single dose of X- or gamma-radiation is no greater than if the same total dose is delivered in two discrete fractions with intervals of as much as a month between them (Sacher, G. A., personal communication); there is no evidence with the single dose of the interaction that would be expected if 'two-hit' chromosome structural damage were important. Similarly, the relative biological efficiency for life-shortening of fast neutrons compared with X- or gamma-radiation does not increase if the dose is given in several fractions, provided the dose-rate during the actual irradiations is the same[40b,42]. These results suggest that the greater life-shortening efficiency of single doses of X- or gamma-radiation compared with chronic low dose-rates is a dose-rate phenomenon perhaps comparable with the dose-rate effect for mutations in mice[43]. If the primary intracellular process responsible for life-shortening is dependent upon dose-rate, then it cannot be equated with 'one-hit' chromosome structural damage[41]. On the other hand, fractionation of X-ray dose without change of dose-rate has in some experiments produced a decreased efficiency of life-shortening, either in absolute terms[44] or relative to the fast-neutron effect[45]. It is known for cells generally that there are qualitative differences in the spectrum of chromosomal changes produced by single and protracted doses of X- or gamma-radiation or by single doses of different magnitudes, owing to the dependence of the 'two-hit' component on time of exposure and square of the dose. These differences might lead to differences in the ensuing intercellular dynamics, which might help to account for some of the facts observed. In general, however, the influence of possible specific disease processes requires more detailed examination[46]. Thus the possibility that the primary intracellular change is one of chromosomal structural damage cannot be ruled out.

The simpler formal model that the intracellular change responsible for ageing is gene mutation[16,17] offers no simple explanation of a possible dose-rate effect for X- or gamma-radiation, or for the large size of the 'doubling dose'. A chronic dose-rate of about 13 rems/day is required to double the rate of ageing in mice[35], so that the doubling dose per life-time is around 5,000 rems or 1,500 rems as a single dose, which as Strehler[12] points out is about 25 times larger than the genetic doubling dose. It may be that the site damaged is not part of a chromosome at all; ageing in some organisms seems to be primarily a cytoplasmic phenomenon[47].

The bearing of the evidence on the relative biological efficiency of fast neutrons compared with X- or gamma-radiation for life-shortening on the nature of the intracellular change is ambiguous. The relative biological efficiency for single doses[40] is around 2, and for chronic doses[31,32] around 10. Data on the relative biological efficiency for point mutations are not available for mouse cells. Early work on muta-

tions in *Drosophila*[41] gave values of about 1 with single doses, but more recently values near 2 have been found[48]. The relative biological efficiency of single doses of fast neutrons for chromosome damage depends on dose-level and the particular type of damage.

Examples of possible consequences of cell-change which would be relevant to ageing are: (*a*) death of non-replaceable cells; (*b*) reduced competence for particular functions; (*c*) auto-immune reactions between changed and normal cells or between changed cells themselves. Burnet[49] has suggested that ageing may be an auto-immune reaction, and this may perhaps be the essential character of what is here described as development, and most of the cells of the animal may be involved. The cells changed by the induction process may comprise all the cells, or only some particular class of cells. If induction is a process of destruction of a special class of cells, they might correspond to the homœostatic systems postulated by Burnet[50], damage to which beyond a certain level unleashes an uncontrollable chaos of reactions from spontaneous auto-immunity leading to physiological deterioration and finally death.

The idea of ageing as a gradual increase in entropy was early suggested by Perks[51], and more recently formal treatments have been given in terms of information theory[17,52]. The precise meaning of the formalism is not always clear, however; for example, How much of the information in the organism is intracellular and how much intercellular? Would an idealized point mutation in a cell reduce the information of that cell, or is it more important that the cell is now different from its fellows? The incompletely explored distinction between information entropy of form and of function[53] would seem to be important for this question. The loss of information by the whole organism caused by time and chronic radiation may be formally represented:

$$H_0 - f[(1 + \lambda r)t] = H_1 \qquad (5)$$

where H_0 is the initial level of information and H_1 the final level. H_1 is usually interpreted as the value at death, but in my model would be the value at the end of induction. Yockey[17] regards the difference of life-span between individuals as due to genetic differences in the initial level of information and assumes a fixed value for the final critical level.

If, however, loss of information due to induced differences between cells were the important process, so that because of the initial identity of the cells in a given individual all individuals initially contained the same amount of information H_0, the individual variation might be associated with the final level, H_1. That is, there would be individual differences, genetically determined, in the amount of cellular disorder which could be tolerated. This possibility is considered by Quastler[52] and Szilard[54]. There is a third possibility, that individual variation is associated with the term in equation 5 which expresses the effect of time and radiation in reducing information. This is ruled out, so far as radiation is concerned, by the fact that a single dose of radiation produces a uniform shortening of life even though there may be dispersion of induction times; for example, the shortening of life by a single dose in LAf_1 mice is the same in the long-lived as in the short-lived individuals[13,55]. The assumption that individual differences are associated with the final rather than the initial level of information is in harmony with the idea of an increasing divergence between cells leading to auto-immune conflict.

Extrapolation between species for shortening of life by irradiation. There are several difficulties about extrapolating shortening of life by irradiation between species, even if it be accepted that the postulated intrinsic ageing process is the same in different species. In general, the relative importance of this process and the 'accidents' in determining the natural life-time is unknown. Further, for any radiation condition other than very low dose-rates, highly specific processes may be important; even for low dose-rates there have been reports of a prolongation of mean life-time relative to controls[13,20,56].

Boche[57] first suggested that a given dose produced the same proportional life-shortening in different species. This hypothesis has been used as the basis of most attempts to derive the shortening of life per unit dose in man from data on laboratory animals, leading to values from 1 to 15 days per roentgen (or per rem)[14,35,58]. In the present model, however, the shortening of life per rem, λ, is the ratio of 'mutation'-rate per unit time produced by unit dose-rate to that occurring naturally. There seems to be no compelling *a priori* reason why this ratio should increase in proportion to natural life-span, only a loose analogy from the approximate constancy of doubling dose per generation for genetic effects. In organisms as biologically similar as mice and men, it is conceivable that the value of this ratio might be the same, in which case the *absolute* shortening of life per unit dose would be the same, namely, about 0·08 day per rem of chronic radiation. A radiation worker, for example, who accumulated the maximum permissible life-time dose of 200 rems would then suffer a shortening of life of 16 days, instead of a figure of the order of a year derived on the alternative assumption. It is of interest that the life expectation of radiologists does not seem to have been significantly reduced by their exposure to radiation[59].

I am indebted to my colleagues for permission to quote some unpublished material.

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COMBUSTION AND PROPULSION

HIGH MACH NUMBER AIR-BREATHING ENGINES

THE Advisory Group for Aeronautical Research and Development, familiarly known as AGARD to aeronautical scientists, is both the concept and the achievement of one man—eminent mathematician in the field of aeronautics for so long as to have become almost legendary. Theodore von Kármán saw the need immediately after the Second World War for some organization in Europe to recreate the aeronautical strength of those countries which had been prevented from working in the field, and had, indeed, been largely isolated from the very rapid development which had then taken place during the War.

It was clear that such an organization had to be under the general sponsorship of NATO; but the orthodox solution of an international body composed largely of officials and the military was not what von Kármán desired. Instead, he created what was for all practical purposes an international learned society, having the great advantage of being supported financially by a military treaty organization; although depending upon that support, von Kármán has always insisted on an administrative autonomy for AGARD, which has been largely responsible for its scientific independence and quality. He became its first chairman and has been unanimously re-elected to that post each year since.

AGARD held its fourth Combustion and Propulsion Colloquium, on "High Mach Number Air-breathing Engines", in Milan during April 4–8. Appropriately enough, the sessions were held in the Museum of Science and Technology erected to the memory of that illustrious and most famous citizen of Milan, Leonardo da Vinci; so, surrounded by copies of diagrams from the master's sketch book and working models which showed he had, in any event, considered these problems ages ago, some three hundred and seventy scientists from most of the free European nations, the United States and Canada met for discussion. The team from the United States was extremely strong, and, as would be expected, made the largest and most vigorous scientific contributions, undoubtedly due, in part, to a very liberal interpretation of the security regulations by the American authorities.

The choice of the subject of high-speed, air-breathing engines, in the current fashion for space science, is possibly unusual. In the United States it appears that official support for research into air-breathing engines has largely been terminated in favour of the extensive programmes of rocket research and development for space exploration. The gigantic air-supplying plants at the experimental establishments of the National Aeronautical and Space Agency and the U.S. Air Force which were originally built for gas turbine and ram-jet research have been almost entirely converted into test facilities for rocket research.

It became clear in the opening speeches of the colloquium that the above state of affairs was causing a good deal of concern in many scientific quarters in the United States. Indeed, the first four papers, all by Americans, were in the nature of both an apologia and an explanation for the choice of subject. Von Kármán, in his opening address as chairman, pointed out that although one of the first to advocate the missile and rocket applications to flight, he now felt that the very enthusiasm with which this challenging branch of science and technology had been taken up was causing an unbalanced programme of research

and development. He said that it was not unreasonable to expect that, considering the limitations of human physiology, the urge for yet faster manned flight through the atmosphere would be more attractive and more useful than a few space explorations using ion or plasma engines utilizing nuclear power and lasting for several years.

At present, military manned aircraft fly at twice the speed of sound, and engineers are considering seriously the building of civil airliners which will cruise at least as fast. Well-behaved missiles cruise at Mach 10–20, and von Kármán felt that it was in the intermediate range of Mach 3–10 that useful developments could take place, but only if really serious scientific effort was applied to the many research problems involved.

On the military side, von Kármán said that he strongly suspected that future study of the problems would show that the role of manned aircraft was, as yet, far from being terminated and that the development of vertical take-off techniques would broaden even further the usefulness of very high performance aircraft using air-breathing engines.

In the second paper of the opening session, Admiral J. T. Hayward, the only military speaker, who is deputy chief of development, U.S. Department of Navy, supported the same view, pointing out "the advantages of using an oxidizer, which is there for the asking". He went on to describe certain broad fields of military applications of very high speed, air-breathing engines both in missiles and manned aircraft.

Both the first two speakers said that developments of the ram-jet engine appeared to be the likely solution at speeds between Mach 5 and 8, although the disadvantage of this type of engine in having no static thrust and hence having to depend upon some other form of propulsion for take-off was stressed by Admiral Hayward.

The rest of the programme did indeed concentrate upon the problems of ram jets, apart from one session devoted to turbo-machinery. Before this, however, there were two more introductory papers by Prof. A. Ferri, of Brooklyn Polytechnic, and by M. A. Zipkin and L. M. Nucci, of the General Electric Co., which were devoted to somewhat superficial parametric studies of the different applications of ram jets in both the manned and missile fields, which the authors thought would be important in the future.

Ferri pointed out that in certain applications an air-breathing machine is the only practical solution, while in others it is an alternative to the rocket. In the former category he placed transportation and tactical warfare and in the latter a number of missile applications.

In the case of transportation, Ferri said that increase of flight speed not only decreased transit time but it also increased the range of an aeroplane. He pointed out that a great many of the major cities of the world were about 5,000 miles apart, and an aeroplane with such a range would be commercially attractive. It could only be attained economically by flying at Mach numbers of 4–8 rather than 2 or 3 and would use ram-jet engines for cruise, and turbo-jet engines designed essentially for the accelerating phases.

He also described a system for placing a large payload into orbit; and then landing without damage. Such a vehicle would take off like an aeroplane using turbo-jet engines, accelerate gently to orbital speed under full control in time and position, using ram-jet engines with subsonic burning in the lower range of supersonic flight, but at hypersonic speeds the internal flow in the combustion chambers would be supersonic. Such a vehicle would weigh between 130,000 and 400,000 lb. at take-off and could place a payload of 10,000 lb. in orbit. Although requiring much basic research, Prof. Ferri felt such a vehicle would be far more efficient and far more useful than present solutions based entirely on very large rocket motors. He made a strong plea for a small but continuing research effort in the air-breathing engine field, pointing out that if not, the existing technological ability and scientific background accumulated in many years of work would be lost. He considered that a resumption of such work at a much later date would necessitate a far larger effort.

Zipkin and Nucci elaborated the theme of composite, air-breathing systems, reviewing the performance characteristics of present engines and the trends of improvements in future engines. Performance figures from this work were then used to study a number of applications.

The first was the use of an accelerating air-breathing first stage for launching satellites or sounding rockets. In these systems, the launching vehicle might be a supersonic fighter or other very high performance aeroplane which would release the final rocket stage at 60,000–80,000 ft. Such systems, on the authors' assumptions, showed gains of as much as 60 per cent in the ratio of orbital weight to take-off weight, as compared with two-stage rocket systems. It is worth noting that the launching structure weight is much higher in the former case, but since the launcher is not expendable, a net saving in cost should ensue if the number of launchings was high enough, together with a much greater flexibility of operation since satellite launching programmes could be undertaken from conventional airports. This, in itself, would also lead to a much greater choice of initial orbit inclinations.

The second system studied by Zipkin and Nucci was a composite supersonic transport, capable of transporting sixty passengers 3,500 miles at Mach 4. Again, there were two stages and, as would be expected, the staged system was about two-thirds the weight of a single aeroplane, and less fuel was consumed by the former. This is not a convincing example, since a similar, if less strong, argument for staging can be applied to present subsonic transports, again with similar performance gains. In fact, such systems have been tried (for example, the Mayo composite aircraft), but have never been attractive to operators because of the much greater capital and maintenance costs, and of the difficulties of operation.

The main part of the colloquium dealt with the research necessary to develop ram jets up to hypersonic speeds between Mach 4 and 10. Essentially, a ram-jet engine consists of three components, namely, an air intake, a combustion zone and an exit nozzle. Air must be efficiently decelerated and compressed in the intake, then energy added by burning fuel in the air stream and finally the heated gas is accelerated and expanded to ambient pressure. At speeds of around Mach 3–4 such processes are reasonably straightforward, although, since most of the work takes place in the intake and exit nozzles, ram jets are extremely sensitive to exact matching of the three components, otherwise useful thrust (that is, thrust greater than drag) will not result.

As speeds increase into the hypersonic regions, the difficulties increase greatly. In the first place, the stagnation temperatures at hypersonic speeds are very high (around 5,000° R at Mach 8), even though the ambient temperature of the air is that associated with the stratosphere. There appears to be, indeed, a propulsion 'corridor' to high performance which relates altitude and Mach number, and bordered on one hand by maximum stagnation temperature and maximum internal working pressure, and on the other by minimum pressure for combustion. While much can be done to alleviate the temperature problem by radiation cooling and by using the evaporation of the fuel, there remain extremely serious material problems which were discussed at a later session of the colloquium. It is of interest to note that there is the possibility of compressing the air externally under a hypersonic wing, and spraying fuel into the decelerated flow. In other words, the ram jet can possibly be turned inside out with a very great gain of radiation cooling.

The design of an efficient air intake for one particular hypersonic speed is not difficult. However, in any practical ram jet the efficiency must remain high over the wide range of speeds and altitudes through which the engine accelerates to the cruise condition. This necessitates great variations in the shape and area of the intake. Ideally, a continuous variation is required, but, in general, the weight involved forces compromise solutions.

In all current ram jets and turbo jets, the air is decelerated in the intake to subsonic speed; but in the case of the hypersonic ram jet the problem of the intake would be eased if only partial deceleration took place. This, however, throws a greater burden on the design of the combustion chamber since little is known about stable combustion in a supersonic air stream.

It is of interest to note that, at hypersonic speeds, kinetic energy recovery is a more convenient way of expressing the adiabatic efficiency of an intake rather than the pressure recovery ratio used at lower speeds.

Finally, the exit nozzle has also to be designed to deal with the same wide range of Mach numbers and altitude as the intake, and consequently variable geometry is once more necessary. There are, however, two additional difficulties: first, the extremely high gas temperatures severely limit mechanical solutions. The second difficulty is of a more fundamental nature. The transit time of the air through the engine is of a similar order to the recombination times of the dissociated products of combustion. At present there is a great deal of uncertainty as to the amount of recombination which takes place before the hot gases leave the nozzle, the difference between the thrust of the equilibrium flow and the 'frozen' flow thrust of complete dissociation being enough to rule out the latter as leading to a useful engine with a thrust greater than its drag.

It will be seen, therefore, that the development of air-breathing engines for hypersonic propulsion throws open new fields of research, both in gas-dynamics and thermodynamics, which are likely to be very fruitful. The authors of the papers which followed had accepted this challenge, and presented a great deal of new and valuable work, none the less interesting because of its controversial nature. Indeed, the discussions, which at conferences of this nature are not usually very stimulating, were on occasion extremely brisk.

Both J. A. Drake and C. L. Dugger, of Johns Hopkins University, presented papers dealing with the ram jet as an entity. The former especially stressed the need for additional research effort in the determination of exhaust nozzle recombination rates. Dugger's paper consisted of a theoretical comparison of hypersonic ram jets with subsonic and supersonic combustion. His calculations assumed that stable combustion can be achieved in supersonic flow, an assumption which is open to some doubt on present evidence.

On the basis of equilibrium flow, Dugger predicts that a significantly better performance can be achieved with supersonic combustion than with subsonic at speeds in the Mach 8–10 range; in addition, lower combustion chamber pressures and temperatures may ease the design problems. However, making further assumptions about the degree of recombination, he showed that when kerosene is the fuel, the supersonic combustion chamber must be operated at pressures almost the same as in the subsonic case in order to achieve reasonable performance.

The next session was devoted to two papers by J. F. Connors and L. J. Oberry, of the National Aeronautical and Space Agency, and G. H. McLafferty, of United Aircraft, describing basic studies on air intakes. Intakes with both internal and external compression were examined and the great importance of variable geometry in both cases was emphasized. It was also shown that difficult viscous effects will be present which will necessitate complicated boundary layer control devices for maximum performance.

In logical order, the following sessions were devoted to combustion problems and to investigations of the reactions taking place in exit nozzles.

H. Behrens and F. Roessler, of the historic rocket establishment at Saint Louis, which is now under combined French and German direction, described some elegant experiments with supersonic diffusion flames, obtained by passing a supersonic jet of the hot, but not fully oxidized, gases from a solid rocket into air or oxygen. It was shown that with propellants of high heat of explosion stable flames were produced with no ignition delay at the first shock of the jet, while with propellants of low heats of explosion, ignition occurred with a delay, behind the first shock. The latter flames became unstable as the heat of explosion of the rocket propellant became less, although a greater stability was achieved with pure oxygen than with air.

P. P. Wegener, of the Jet Propulsion Laboratory, California Institute of Technology, chose the simpler and better-known system of a reacting mixture of nitrogen tetroxide and dioxide carried through a supersonic nozzle with a stream of nitrogen. By choice of conditions flows which were either in chemical equilibrium or in states between equilibrium and 'frozen' flow could be obtained, the recombination co-efficients being determined from optical absorption or static pressure measurements. As was pointed out in the discussion by K. N. C. Bray, of the University of Southampton, these experiments gave excellent agreement with his own theoretical predictions about non-equilibrium flows through supersonic nozzles and shock-waves.

E. A. Lezberg and R. B. Lancashire, of the National Aeronautical and Space Agency Lewis Research Centre at Cleveland, Ohio, described similar nozzle

investigations on a much larger scale using hydrogen/air mixtures. In this case the rate of recombination of the dissociated products of combustion was derived indirectly from performance calculations based upon static pressure and temperature measurements. The results indicated that although deviations from equilibrium flow occur downstream of the nozzle throat, recombination may be occurring throughout the length of the nozzle.

A further paper in the combustion series was a distinguished contribution by A. K. Oppenheim and P. A. Stern, of the University of California, in which the applicability of detonation wave studies to hypersonic combustion was investigated. The authors pointed out that the very stability of a detonation wave makes possible very precise observation and measurement, which could lead to an understanding of many of the problems in a ram jet, such as, for example, the propagation of non-equilibrium disturbances through compressible and reactive gaseous mixtures.

Detonation waves discovered by the early classical work of Berthelot Le Chatelier and others were studied from a thermodynamic point of view by D. L. Chapman and E. Jouget around the turn of the century. These workers demonstrated that detonation waves are complicated systems of shock waves followed immediately by deflagration; and later work, by means of more sophisticated instrumentation, has enabled the structure of the wave-front to be examined in much greater detail. It is clear that the team at the University of California has made great advances in this fascinating field of thermodynamics.

Not the least useful part of the paper by Oppenheim and Stern was the historical review of earlier work on detonations and explosions, together with more than two hundred references to other published work. The paper may well, therefore, become a standard reference in this field.

Following these papers on thermodynamics was the only paper on gas-turbine engines, somewhat out of context, since the speed-range considered was only up to Mach 3, and somewhat unfortunate in that it was one of the only two British papers. Nevertheless, it did reflect the emphasis in Britain of the continued importance of the lower Mach number range. Prof. J. H. Horlock, of the University of Liverpool, presented a very interesting paper on the research in turbomachinery which was still essential for the development of gas turbines capable of propelling aircraft at speeds up to Mach 3. He reviewed the current work on component efficiency, stability of compressors, blade cooling and maldistribution in the intake and compressor, all fields in which he considered there remained many problems requiring fundamental research.

Curiously, no mention was made of combustion problems which are certainly not well understood at Mach 3, nor was there any reference to the great difficulty of dealing with the noise caused by such engines, which may be a dominating factor in the choice of efflux velocity and relative mass flow.

Again, this paper contained a very useful list of nearly sixty references to the published literature.

Finally, the last session was devoted to the materials problems raised by the very high temperatures of hypersonic air-breathing engines. Papers were presented by A. J. Murphy and A. J. Kennedy, of the College of Aeronautics, Cranfield, and by P. Duwez, which were remarkable for their similarity of thought —indeed, each contained an identical diagram relating activation energies for creep, stress rupture and self-diffusion with melting temperature. Working on these lines, but also grading on a basis of low density and high elastic modulus, the advantages of tungsten, molybdenum, chromium and beryllium as refractory materials were stated. Duwez pointed out that since ram jets were constructed mainly from sheet, metals were more attractive than cermets or ceramics; but Murphy and Kennedy stressed the surface reactivity of such metals and the need for research in surface protective methods. Both papers also referred to the use of graphite, with its very high sublimation temperature and its unusual property of increasing tensile strength with temperature up to about 2,500° C.

Duwez, however, considered that materials research would not provide the entire answer to these high-temperature problems, and that porous wall cooling and ablation would be the ultimate solution for very high combustion temperatures. In the ensuing discussion, it was generally felt that the ultimate limit was likely to be an economic one.

So came to an end an extremely useful and fruitful colloquium, which provided an excellent forum for vigorous discussions in a relatively new field of applied science. As is general with AGARD meetings, the contribution of the American workers was both massive and excellent. Unusual, however, was the rather small contribution from Great Britain, the representatives of which were, in general, in the position of assimilating, rather than contributing, new information.

W. Cawood

THE PLANT PATHOLOGY LABORATORY, HARPENDEN

By W. C. MOORE, C.B.E.

THE Minister of Agriculture, Fisheries and Food, the Right Hon. John Hare, formally opened the new buildings of the Plant Pathology Laboratory at Hatching Green, Harpenden, on May 13, in the presence of more than a hundred distinguished guests and a staff of nearly sixty. The Minister recalled that the Laboratory, familiarly known for years as "Path. Lab.", was one of the oldest scientific sections of the Ministry. It was founded in 1918 at the Royal Botanic Gardens, Kew, and three years later was transferred to a converted private house in Harpenden. During the next twenty years it had consolidated its position as a scientific liaison centre and a source of advice on all aspects of plant diseases and pests. The big development of the Laboratory had come in the past two decades along with advances in the study of crop protection. The Second World War had again focused attention on maximum food production, and with the need to cut down losses from diseases and pests the Laboratory became an impor-

Fig. 1. General view of the Plant Pathology Laboratory, Harpenden, from the rear. (Photo by E. C. Large)

tant link in the complex relations which exist to-day between science, industry and the farmer. A private house was well enough with a staff of ten; but it became more and more inadequate as the work and staff increased. By 1955 the problem of accommodation had become acute. It was then that the Lawes Agricultural Trust purchased and leased to the Ministry of Works a site of nearly six acres on which a new Laboratory could be built, and during the period of construction it provided temporary accommodation for a substantial part of the overcrowded staff.

The new building lies on the periphery of the Rothamsted Experimental Station campus and its design is well adapted to the functions of the Laboratory, which are essentially still of a liaison nature. For example, the Laboratory co-ordinates a system of intelligence, survey and forecasting work on plant diseases and pests, and this involves almost daily contact with the regional plant pathologists and entomologists of the National Agricultural Advisory Service. It provides the scientific basis for the administration of regulatory work involved in the import and export of plants, in the internal spread of dangerous plant diseases and pests, and in official crop certification schemes for potatoes, fruit and hops, all of which is done in the closest collaboration with the Ministry's Plant Health Branch, the National Agricultural Advisory Service, and the Plant Health Inspectorate. It also works closely with the chemical industry in so far as it acts as a clearing house for information on the toxicity of insecticides, fungicides and herbicides to man, animal and plant, and houses an Agricultural Chemicals Approval Organization recently set up to grant official approval to biologically efficient proprietary chemicals used in crop protection, and to replace a somewhat similar scheme that had been in operation for nearly twenty years. The Laboratory also prepares and keeps under regular revision the Ministry's advisory leaflets and bulletins on common diseases and pests of plants, edits its own quarterly journal, *Plant Pathology*, and carries out research on problems arising out of administration. Collaboration in the work of inter-governmental organizations such as the European and Mediterranean Plant Protection Organization, the Western European Union and the Food and Agriculture Organization has become an important feature of its activities during the past decade.

The new building does little more than accommodate the present staff of sixty, including thirty-five plant pathologists, entomologists and chemists; but its construction and L-shaped design are such as to allow for ready expansion. The spacious entrance hall gives access to two corridors along which the laboratories and offices for plant pathology and crop protection chemistry are arranged on either side. The third department, for agricultural entomology, and the library are on the first floor above plant pathology. The chemistry wing has a flat re-inforced roof to allow for first-floor extension. About thirty of the rooms are designed to serve the double purpose of office and laboratory. In addition, there are two chemistry research laboratories, three air-conditioned rooms and a laboratory for experimental work on fumigation, separate laboratories for mycology, nematology and bacteriology (including the housing of the National Collection of Plant Pathogenic Bacteria), a combined conference and training room, photographic department, library, insect museum, general office, and workshop.

The two chemistry laboratories are identical in design, and are intended for the chemical evaluation of formulations in one, and of pesticide residues on crops in the other. To save wall space each is virtually divided into two by a central peninsula of four fume cupboards equipped with separate speed-controlled exhaust fans and external air intake fans, thus avoiding warm air being sucked out of the room. Titration benches and laboratory scaffolding with lateral service panels occupy the ends of each laboratory. Hot and cold water, electricity, gas, vacuum, compressed air, distilled water, carbon dioxide and nitrogen supplies are fed to the working benches and units from a service duct under the central corridor. Between the two laboratories are the balance and electrical equipment rooms housing a spectro-

photometer and allied instruments. There is also a general purpose chemical laboratory containing large apparatus, such as a centrifuge and a deep freeze, and provided with fixed service panels and mobile benches to allow flexibility of arrangement.

Techniques for controlling pests on planting material either imported or destined for export will be studied in a new fumigation section, starting with methyl bromide fumigation of seeds and continuing with the effect of fumigants on a number of pests and plant species. A large general-purpose laboratory is intended to be used for gas analysis studies and for the biological aspects of the work. In the three air-conditioned rooms temperatures can be controlled between 5° and 30° C., and high relative humidities can be maintained, in order to be able to simulate some of the conditions which obtain during practical plant quarantine work. One room will house a 1,500-litre steel fumigation chamber for plant toxicity studies and for work on vacuum fumigation techniques, while the other two will be used for small-scale studies on the sorption of fumigants by seeds and for the rearing of insect pests.

Ancillary buildings adjoin the main laboratory. The glasshouse block includes insectaries, glasshouses of a total area of 2,000 sq. ft. divided into a number of isolated compartments, a small laboratory for plant inoculations, and a working area with potting bench, etc. Ventilators are protected by removable metal gauze panels, so that any compartment can be made aphid proof. The virus disease section has additional forced fan ventilation. The bench tops are concrete troughs so that the plants can be watered by sub-irrigation. The glasshouses are heated by small-bore hot-water pipes and auxiliary electric fan heaters, both thermostatically controlled; and there are facilities for supplementary lighting when required.

The ancillary buildings also include a room specially designed for washing soil samples to determine pest populations of soils, and a pest assessment sample room equipped to deal annually with large numbers of experimental yield samples of cereals and forage crops. A small, unique, electrically driven, highly versatile, loss-free threshing machine, designed and built at the National Institute of Agricultural Engineering, has been installed along with other equipment, including a sample dryer which can deal with wet samples before threshing as well as grain after threshing, and a modified small commercial grain cleaner.

OBITUARIES

Mr. H. W. Robinson

H. W. Robinson, who died suddenly on April 22, was a familiar and much-consulted figure in the Library of the Royal Society, with which his association was so long, so close and so valuable that the loss seems irreparable. He was born on March 23, 1888, in Wood Green, a part of London with which he was closely associated all his life, being in many ways a prominent local figure, held in affectionate regard by the residents. He joined the staff of the Royal Society in 1902, as a boy of fourteen, and soon became particularly associated with the Library, of which he was appointed assistant librarian in 1930 and librarian in 1935. When, at the age of sixty, he retired from this post, his services were retained by the Society to assist in editing the Newton correspondence, of which, happily, he was spared to see the appearance, some months ago, of the first of the seven volumes that are anticipated. With this work, to which his contributions were a model of clarity and accuracy, he was prominently associated until the day of his death.

Robinson took an enthusiastic interest in everything to do with the Royal Society's Library and with its extensive and invaluable archives. He was a self-taught scholar of considerable attainments, whose specialized acquaintance with many branches of the history of science was remarkable. He was always ready to place this exceptional knowledge, which included the whereabouts of rare books and manuscripts other than those in the Society's possession, at the disposal of students of the history of science, including many from abroad who made use of the Library, and frank acknowledgments of his generous and valuable aid are to be found in many important publications. With Prof. Harcourt Brown and Prof. D. M. McKie he founded the *Annals of Science* and he took a prominent part in founding the British Society for the History of Science.

He was particularly well acquainted with the events of the early days of the Royal Society. He had, for example, made a particular study of Robert Hooke: he identified as written by Hooke the diary in the British Museum that had always been attributed to James Petiver, and, in conjunction with Walter Adams, he edited the "Diary of Robert Hooke", in the possession of Guildhall Library, which was published in 1935. Reference has already been made to his exceptional knowledge of the correspondence of Newton and his contemporaries.

Robinson was a most friendly man, who knew his own mind and inspired confidence. He was devoted to the Royal Society, which he served for fifty-eight years, and the Society repaid his devotion with a warm regard and a respect for his specialized knowledge and achievements. He was very happy when his son Norman was appointed assistant librarian to the Royal Society, thus continuing the association which Robinson himself so long represented.

E. N. da C. Andrade

Mr. J. R. MacCabe

Jack R. MacCabe, a familiar figure to the many visitors to the European Organization for Nuclear Research, died on April 17.

Born at Edmonton, Canada, on May 4, 1914, he entered the University of Alberta in 1930. Two years later, he went to McGill University, Montreal, where, by 1937, he had taken his degrees of bachelor of science and master of science (natural sciences), while working as a demonstrator and lecturer in physiology at the University's Faculty of Medicine.

Jack MacCabe went to Europe soon after finishing at McGill and continued medical and biological studies and research at the University of Munich, up to the outbreak of the Second World War in 1939. When he arrived in Switzerland, he found a position as a lecturer at the International School and at the

Interpreters' School of the University of Geneva, where he remained until 1944. In the meantime, in 1942, he had joined the staff of the well-known aviation magazine *Interavia* and, in 1951, became executive editor of its "Air Letter".

In September 1955, he joined CERN (European Organization for Nuclear Research) and eventually became senior information officer. His considerable energy and intelligence were used to good purpose in meeting the thirst of the informed public for more information about the Organization and in bringing CERN'S existence and achievements to the notice of the lay press and public. He was extremely successful in putting across to visitors the philosophy, the technology and the science of CERN, and his broad outlook and his pleasant personality had won him countless friends among the many visitors to the Organization.

NEWS and VIEWS

Wolfson Research Professorship of the Royal Society : Dr. Dorothy C. Hodgkin, F.R.S.

Dr. Dorothy Hodgkin has been appointed by the Council of the Royal Society as the first holder of the Wolfson research professorship, endowed by the Isaac Wolfson Foundation. Dr. Hodgkin gained recognition as an expert in X-ray crystallography early in her career, while still working with Bernal, contributing frequently to the crystallography section of the Chemical Society's Annual Reports from 1933. Educated at Somerville College, Oxford, she returned there as chemistry tutor ; later she was appointed as University reader in X-ray crystallography and became a Fellow of the College. Academic distinctions came quickly—honorary D.Sc. of the University of Leeds, election in 1947 as one of the small handful of women Fellows of the Royal Society, and a Royal Medal of the Society in 1956. She is also a foreign member of both the Netherlands and the U.S. Academies of Sciences. Instead of choosing between career and family, Dorothy Hodgkin has made a brilliant success of both, with three children and one grandchild to her credit, besides being a charmingly informal hostess. With the help of devoted groups of research students, she has contributed much new knowledge to her chosen field of X-ray crystallography. More significantly, however, she has forged ahead in seemingly impossible directions with the investigation of ever more complex biological molecules—calciferol, cholesterol, penicillin, a virus, and finally vitamin B_{12}. With intuitive insight she can not merely extract the utmost information from a complex round of calculations, but can also make the next round uncannily informative by inspired predictions. As research professor she will remain at Oxford to continue this work.

Barnard Medal of Columbia University, New York : Prof. I. I. Rabi

Prof. I. I. Rabi, Higgins professor of physics at Columbia University, New York, has been awarded the Barnard Medal for 1960 for "meritorious service to science". The award, presented every five years by the Trustees of Columbia University, is made on the recommendation of the U.S. National Academy of Sciences. Dr. Rabi was born in Rymanow (old Austria-Hungary) in 1898. He graduated from Cornell University in 1919 with a bachelor's degree in chemistry ; he received his Ph.D. in physics from Columbia in 1927. He has taught at Columbia University since 1929. In 1940 Dr. Rabi and a group of physicists organized the Radiation Laboratory at the Massachusetts Institute of Technology ; the laboratory was devoted to the development of radar for military purposes. He was awarded the Nobel Prize for physics in 1944 for the general application of the resonance method to the magnetic properties of atomic nuclei. During 1952–56 he was chairman of the general advisory committee to the U.S. Atomic Energy Commission. He is a member of the President's Science Advisory Committee and was chairman in 1957.

The Barnard Medal was established by the will of the late Dr. Frederick A. P. Barnard, president of Columbia University during 1864–89. It is presented to "the person, if any, whether a citizen of the United States or any other country, who within the preceding five years has made such a discovery in physical or astronomical science, or such a novel application of science to purposes beneficial to the human race, as in the judgment of the National Academy of Sciences of the United States, is esteemed most worthy of such honor". Former Barnard medallists include Albert Einstein, Niels Bohr, Enrico Fermi, Frédéric Joliot and Mme. Irène Joliot-Curie, and M. A. Tuve.

United Kingdom Scientific Mission in Washington : Dr. H. T. Hookway

Dr. Harry T. Hookway has been appointed director of the United Kingdom Scientific Mission in Washington, D.C., and scientific attaché at the British Embassy there. He will succeed Mr. E. S. Hiscocks, who is returning to Britain in the autumn on completion of a three-year tour of duty to become director of the Tropical Products Institute. Dr. Hookway, who is thirty-eight, is the assistant director of the National Chemical Laboratory, where he has been since joining the Department of Scientific and Industrial Research in 1949. He is well known for his work on polymers, ion-exchange resins and saline-water conversion, and was the United Kingdom representative on the International Steering Committee for Co-operative Research in Electrodialysis (the purification of brackish water) during 1953–58. Educated at the Trinity School of John Whitgift, Croydon, and the University of London, Dr. Hookway held research posts in industry, working on oil additives, before becoming, in 1947, lecturer in organic chemistry in Battersea Polytechnic (now the Battersea College of Advanced Technology), where he obtained his Ph.D. in 1949.

Seismological Observatory, Wellington, N.Z. : Mr. R. C. Hayes

On May 31, Mr. R. C. Hayes, superintendent of the Seismological Observatory, Wellington, New Zealand, retired after forty years scientific work in the N.Z. Government service. He joined the staff of what was then the Hector Observatory in 1920, and

worked under the late Dr. C. E. Adams until 1936, when he was appointed acting-director of what had become the Dominion Observatory. In 1948, the Observatory assumed its present name, and Mr. Hayes became director. This title was changed to superintendent when the Observatory became part of the Geophysics Division of the N.Z. Department of Scientific and Industrial Research in 1951.

Under the direction of Mr. Hayes, N.Z. earthquake recording grew from two Milne pendulums—at Wellington and Christchurch—to a network of modern instruments extending from Afiamalu in Samoa to Scott Base in the Antarctic. He has pioneered many branches of seismological work in the south-west Pacific, publishing papers on deep-focus earthquakes, crustal structure, ground tilting, and the general seismicity of the region, as well as assuming the responsibility for a growing burden of standard measurements, and training the staff to deal with them. He was the first to direct attention to the appearance of the phase *sScS* in seismograms, and to its usefulness as an indicator of focal depth. The work of the Observatory also included the keeping of a national time service; and during the International Geophysical Year, Mr. Hayes undertook the organization of the N.Z. latitude and longitude programme. He personally made many of the observations with the Danjon astrolabe, as well as undertaking an augmented programme in seismology. Observational astronomy has been an important spare-time interest, and for many years Mr. Hayes carried out regular sunspot observations from his home at Karori. He also made a complete sweep of the southern heavens with a 4-in. refractor, and compiled a catalogue of all the nebulæ, clusters, and double and coloured stars visible through it. In addition to his scientific interests, Mr. Hayes is a keen musician and a church organist.

Crystal Physics at Cambridge : Dr. W. A. Wooster

A FAREWELL dinner was given on June 10 by Prof. C. E. Tilley, head of the Department of Mineralogy and Petrology at Cambridge, to mark the retirement of Dr. W. A. Wooster. Invited by the late Prof. A. Hutchinson to start courses for undergraduates in theoretical and experimental crystal physics, Dr. Wooster was appointed in 1927. These courses, in conjunction with courses in X-ray crystallography, have formed a good basis for the understanding of the modern science of crystals. Dr. Wooster has published two books, "A Text-book of Crystal Physics" and "Experimental Crystal Physics", the latter of which has been translated into four foreign languages. During the War, in collaboration with his wife, Dr. Wooster established a private laboratory where it was possible to make some contribution to the national needs in connexion with diamonds and quartz crystals. The first hydrothermal synthesis of quartz in Britain was carried out in this laboratory. Dr. Wooster has also been concerned with the development of X-ray crystallographic instruments. During the past decade he has worked in the Cavendish Laboratory on diffuse reflexions of X-rays from crystals, and with his research students he has developed methods of determining the elastic constants of crystals. Dr. Wooster intends to do research work in his own laboratory and to continue his efforts for international co-operation in science through the World Federation of Scientific Workers.

Mullard Cryomagnetics Laboratory at Oxford

THE development of iron-free magnets giving large magnetic fields over a fairly large volume has been in progress at the Clarendon Laboratory, Oxford, using a 2-mW. generator installed in the Simon Building in 1949. Such magnets led to success in nuclear orientation experiments in 1951, and nuclear cooling experiments in 1956. At present the magnets give fields up to 50 kilogauss over a volume of 500 cm.^{3}, and are used at four 'stations', two of which, owing to the serious overcrowding of the Laboratory in all departments, are housed in a lean-to shack. A much-needed extension of the Simon Building has been made possible by the generous gift of £25,000 by the Mullard Co., together with grants from the Oxford University Higher Studies Fund and other University sources. Two floors of this extension will be devoted to the high magnetic field work, and will be known as the Mullard Cryomagnetics Laboratory. Seven magnet stations are planned, with fields up to about 120 kilogauss. These will be used for further development of nuclear orientation and nuclear cooling under the direction of Dr. N. Kurti, reader in physics, together with work in the field of solid state physics including semiconductors, antiferromagnetics and ferrimagnetics. It is hoped there will be sufficient facilities to accommodate occasional visitors who wish to carry out important experiments requiring high magnetic fields.

The Royal Society of Edinburgh

To help visitors to the Library and Museum of the Royal Society of Edinburgh, the Curator, Dr. Douglas Guthrie, has prepared an account of the many portraits and has added suitable biographical notes ("Year Book of the Royal Society of Edinburgh, 1959–60"). Altogether, the note contains descriptions of twenty former presidents, ten general secretaries and thirty other distinguished men of science. Among the presidents are such well-known names as Sir Walter Scott, who was the only 'literary' president ever to hold office; Sir James Hall; Sir David Brewster, whose mathematical career was dogged by his 'heretical' religious views; Lord Kelvin, president on three occasions; Sir Alfred Ewing, who built up the school of engineering at Cambridge; Thomas Stevenson, a member of the famous family of light-house engineers and father of Robert Louis Stevenson; the famous botanist, Prof. F. O. Bower; Sir Edward Sharpey-Schafer, whose method of resuscitation known as the 'prone-pressure system' became widely adopted; and Sir D'Arcy Wentworth Thompson, "so versatile that he could speak acceptably on almost any subject, even in an age of specialists". Other distinguished men of science include such names as James Watt, William Murdock, Sir Humphry Davy, David Hume, Georges Cuvier, J. J. Berzelius, Lord Raleigh, Sir Joseph Barnes, Sir J. J. Thomson; they reveal the debt which the world owes to the Royal Society of Edinburgh. Portraits of the first four presidents illustrate the paper.

The European Federation of Corrosion

THE British Association of Corrosion Engineers has been elected a member of the European Federation of Corrosion. The object of the Federation. which is a non-profit making union, is to promote European co-operation in the field of research on corrosion and methods of combating it for the benefit of the community at large. Membership of the Federation is

restricted to non-profit-making European technical and scientific societies the activities of which are connected with the field of corrosion or the protection of materials. The Federation seeks to achieve its objects by convening joint European meetings for the discussion of subjects of general interest; by convening meetings of working parties for the discussion of specific problems; by the creation of working groups for investigating special problems; by the organization of study trips; and by other means. The General Secretariat of the Federation is managed jointly by the Dechema in Frankfurt a.M. and the Société de Chimie Industrielle in Paris.

The British Association of Corrosion Engineers was formed last year (see *Nature*, **183**, 1779; 1959) generally to promote the dissemination of technical information about corrosion matters; to develop the free interchange of information among members; and to promote such educational and other facilities as may be required for the establishment of corrosion engineering as a recognized profession. Individual membership (two guineas a year) is open to everyone interested and associated with corrosion engineering. The address of the Honorary Secretary is 97 Old Brompton Road, London, S.W.7.

The British Hydromechanics Research Association

The twelfth annual report of the British Hydromechanics Research Association covers the year October 1958–September 1959, in which the membership increased by 14 to 89 ordinary and 104 associate members. Brief summaries are given of some of the research in progress, including the construction of a new apparatus for testing mechanical and radial-face seals, an attempt to explain the sealing mechanism of fabric-rubber seals for reciprocating shafts, and a study of the effects of internal leakage of energy from centrifugal pumps through neck rings. Careful tests with a modern design of a large fan showed that velocity measurements in a rectangular discharge-duct at equidistant points in the cross-section gave results 2·7 per cent or more too high. Work is also complete on model tests for the National Coal Board to study flow-conditions and determine pressure losses in gallery-type fan drift junctions and shaft insets, and experimental work has been completed on the influence of size distribution on the flow-characteristics of liquid/solid mixtures, where the solid particles are larger than about 100 mesh. The National Physical Laboratory electronic simulator has been used to investigate surge problems associated with the design of the siphon draw-off tower for Tryweryn reservoir, and the possibilities of de-priming a siphon while passing a high discharge were also examined. Results have been obtained for the fatigue of four flexible high-pressure hoses, and work continued on a model valve for automatic control systems. As a result of tests on a model of the four tidal gates and diversion channel, and on another large model of one pair of gates for a new tidal outfall proposed by the Cheshire River Board for the River Birkett at Birkenhead, a silt deflector and other hydraulic improvements have been added to the original design and gates calibrated as a means of measuring river flow.

Medical Research in France: the Paris Hospitals

French Science News (No. 1, 1960, January–March) includes a special article on medical research in the Paris hospitals, covering both the more or less autonomous organizations such as the Pasteur Institute, the Cancer Institute, the National Blood Transfusion Centre, the Atomic Energy Commission at Saclay with the d'Orsay Hospital and laboratory and the research centres set up within the Hospitals of Public Assistance. These hospitals include about twenty research organizations which have the advantage of being in intimate contact with the patient any time it is necessary. Some of these centres have been grouped since 1955 into the Claud Bernard Association, founded in June 1953, to facilitate the development of medical and biological research in these hospitals. The article outlines the organization and orientation of research in these various centres, including the leukæmia and blood disease research centre, the research centre for the medical application of isotopes, the allergy and immunology research centre, the renal insufficiency research centre, the centre of immuno-pathology, the biological research centre for new-born infants, the neurophysiology, the pharmacological, the experimental surgery, and the cardiological research centres, the gerontological centre, the medical biochemistry research laboratory, the laboratory for medical biochemical research, the neurorespiratory revival centre of the clinic for infectious diseases, the clinic for medical and social rheumatology, the dietetic and human nutrition research unit, and the gastro-enterological research centres, Saint-Antoine and Bichat Hospitals.

Darwin's Notebooks on Transmutation of Species

In his "First Notebook", on transmutation of species, Darwin satisfied himself that it had occurred when populations were isolated and no longer able to prevent variation that resulted from sexual reproduction, and is normally kept in check by breeding throughout the population. In this way varieties become split off from the species and eventually become species themselves, while old species become extinct, thereby increasing the separation between surviving species, many of which after being split into daughter species become genera. In his "Second Notebook", which represents his train of thought from the beginning of February until the first half of July 1838, Darwin was already concerned with the problem of expressing his views on paper and gave himself instructions for presenting his theory. Like the "First Notebook" (see *Nature*, **185**, 580; 1960), the "Second Notebook" has been edited by Sir Gavin de Beer and issued with explanatory notes (Bulletin of the British Museum (Natural History). Historical Series. **2**, No. 3: Darwin's Notebooks on Transmutation of Species. Part 2. (February to July 1838.) Pp. 75–118. (London: British Museum (Natural History), 1960.) 15*s*.). The "Second Notebook" not only describes Darwin's methods of presenting his theory but, incidentally, gives his views on slavery, education, and "the improvement of women".

English Rural Life

The report of the Museum of English Rural Life for 1959 is, as usual, far more than a formal statement (pp. 22, 5 plates. Reading: Museum of English Rural Life, The University, 1960. 1*s*.). This Museum in the University of Reading is still engaged in its threefold task of collecting objects from the countryside, accumulating a library of documentary information and carrying out research on the material acquired. The Museum is, however, concerned that, owing to lack of financial support, it is not possible

to send experienced field workers on collecting and recording expeditions to obtain information when so much detail is being lost almost daily. A voluntary panel of Museum correspondents gives much assistance and again it is stressed that the Museum is not in competition with other institutions having collections of rural material, but is seeking rather to increase the total amount available for study. Miss Anne Sheppard contributes an illustrated article on traditional dairying which includes a catalogue of the Museum material on this subject. It is emphasized that the rapid increase in milk-production during this century, and the policy of supplying an ever-increasing population with milk and its products, have stimulated scientists and engineers to produce methods and machines far removed from the original crafts.

New Principle in Weaving

THE first new basic principle in the weaving of woollen and worsted cloth to be introduced since the Middle Ages has recently been announced by the Wool Industries Research Association (Wool Industries Research Association. Report of the Director of Research for 1959. Pp. 39. Publication No. 214. Headingley, Leeds: Wool Industries Research Association, 1960). Since foot-power looms were first used, the warp threads have been raised and lowered according to the pattern required; the weft has been shot across and beaten into place by the 'reed' and the selvedges of the cloth have been maintained at their proper width by the 'temple'. Ever since that time—particularly since the introduction of power looms at the end of the eighteenth century—the strain on the warp threads due to beating-up of the reed has been a common cause of the threads breaking. The new invention is the full-width temple of the Wool Industries Research Association, which not only maintains the width of the cloth during weaving, but also virtually relieves the warp threads of all extra strain due to the beating of the reed. The new temple holds the cloth firmly across its whole width about a quarter of an inch behind the place where each new pick is inserted. The essential principle is that the weft is forced into its proper place by means of a reduction of the tension in the cloth rather than an increase of the tension in the warp threads.

The Library Association

BESIDES its reference to approaches made by the Library Association to the Minister of Education, requesting the introduction of legislation to implement recommendations of the Roberts Report, the annual report of the Association for 1959 deals with several matters of interest to the scientist and technologist (pp. 27. London: Library Association, 1960). A deputation met the Secretary and other officers of the Department of Scientific and Industrial Research in July to press the Association's proposals regarding the scope and organization of the National Lending Library for Science and Technology. It was urged that the professional staff of the Library should be chartered librarians, and further representations on the issue of staff were afterwards made to the Consultative Committee for the Library set up by the Department later in the year. A strong protest was made to the Department regarding the composition of that Committee. Criticisms and suggestions regarding the draft regulations for borrowing facilities at the Library were also made at the invitation of the Department. Representations were made to the Publishers Association regarding an increase in the number of imperfect copies, and evidence was submitted to that Association; and in protesting to the American Chemical Society following the large increase in the subscription rates of *Chemical Abstracts*, the Association urged that the concessional rates of subscription granted to teaching institutions should be available to public libraries also. The report records a total membership of 12,536, of which 1,164 are institutional and 3,601 Associates and 1,601 Fellows on the Register at December 31, 1959.

Bibliographical Citation

A SECOND edition of the articles by C. C. Barnard, "Bibliographical Citation", first published in *The Librarian* in 1950, has now been issued to facilitate even wider circulation (Bibliographical Citation. By Cyril C. Barnard. Second edition. Pp. ii+20. Reprinted, with revision, from *The Librarian*, May, July and August 1950. London: James Clarke and Co., Ltd., 1960. 2*s*. 6*d*. net). These notes embody the results of Mr. Barnard's own long experience and of his critical study of what has been written on this subject. The purpose of lists of references, bibliographies and of reading lists is clearly distinguished, and citations of manuscripts of printed books and of periodicals are likewise discussed separately. On the subject of abbreviations for periodicals, Mr. Barnard writes cogently and logically, and for this section alone his pamphlet merits attention by every scientist who is concerned with the citation or location of such references. Elementary as the four canons enunciated by Mr. Barnard appear to be, they are not always observed even by learned and professional societies, particularly those canons relating to ambiguity and to the order of words. These canons prescribe that the abbreviation should be: (1) readily intelligible without the use of a key; (2) free from ambiguities; (3) full enough to enable a reader to find the full title in an alphabetical list of periodicals; and (4) follow the same order of words as the original title. Finally, Mr. Barnard gives some guidance to authors on the arrangement of citations in lists. This scholarly pamphlet could well be widely used in technical colleges and universities to check the widespread habit of imperfect and incorrect citation which all too many graduates appear to acquire as students and maintain uncorrected in their professional life.

A Revised Geological Time-Scale

THROUGHOUT the past year, in the columns of *Nature* and elsewhere, there has been keen discussion on the geochronology of the fossiliferous formations. Until recently the geological time-scale established by Prof. Arthur Holmes in 1947 found world-wide acceptance; but much new evidence on the ages of rocks, deriving principally from argon/potassium and rubidium/strontium datings, consistently demands an extension of this chronology, with the beginning of the Cambrian period carried back from 520 million years to about 600 million years. The full arguments favouring "A Revised Geological Time-Scale" have now been presented by Prof. Holmes (*Trans. Edinburgh Geol. Soc.*, 17, 183; 1960; preprint, price 3*s*. 6*d*., published by Oliver and Boyd, Edinburgh). On this scale the geological periods open at the following dates: Cambrian, 600 ± 20; Ordovician, 500 ± 15; Silurian, 440 ± 10; Devonian,

400 ± 10; Carboniferous, 350 ± 10; Permian, 270 ± 5; Triassic, 225 ± 5; Jurassic, 180 ± 5; Cretaceous, 135 ± 5; Tertiary, 70 ± 2 million years. A contemporary review of much the same data, on "Aspects of Radiogeology", has been published by Prof. C. F. Davidson (*Liverpool and Manchester Geol. J.*, **2**, 311; 1960); and another comparable analysis of "The Distribution of Mineral Dates in Space and Time" has been made in California by Dr. Gordon Castil (*Amer. J. Science*, **258**, 1; 1960). Although in North America the various dated orogenies exhibit a crudely concentric pattern with the younger dates outwards, similar arrangements have not been found elsewhere. On the contrary, the age determinations from Africa, Australia and Eurasia are in direct conflict with the much canvassed hypothesis that the continents have accreted around nuclei of greenstones (see also p. 34 of this issue).

Brain

A recent issue of *Brain* (**83**, Pt. 1), a journal of neurology, includes two communications on the muscular disease myasthenia gravis, one by E. R. Bickerstaff and A. L. Woolf and the other by Violet MacDermot. In both studies, biopsy specimens of muscle from patients were used and the nerve endings studied, following vital staining with methylene blue. Histochemical methods for demonstrating the distribution of cholinesterase were also used by the first authors. In both communications, photomicrographs or drawings show that in the muscle of patients there is an abnormality of the distal nerve fibres with an unusual pattern of nerve branching. Elongation of the motor end-plates was a regular finding. These changes were found in muscles in which the classical staining methods showed no abnormality of the non-neural tissues. The authors were unable to establish any definite correlation between the observed changes and the disorder of neuromuscular transmission, though they make a number of cautious suggestions regarding the possible nature of the primary defect in this disease. Another communication (by R. A. Taylor) describes an unusual family in which, through five generations, certain members have shown attacks of acute neuritis, usually brachial in location. Of 119 individuals, 23 per cent of the males and 22 per cent of the females were affected by the condition, which, the author considers, is transmitted by an autosomal dominant gene with a high degree of penetrance.

Chromosome Numbers in *Amaranthus*

In further studies of the genus *Amaranthus*, Prof. W. F. Grant (*Canad. J. Genet. Cytol.*, **1**, No. 4; 1959) has reported on the chromosome numbers for 30 species. These taxa represent approximately two-thirds of the described species. With the exception of one tetraploid species (*A. dubius*, $2n = 64$), all the species are diploid, and somatic chromosome numbers of 32 (14 species) and 34 (15 species) are found in all sections of the genus. The genus is thus characterized by two basic chromosome numbers, namely, 16 and 17, which are found with equal frequency in the different taxa. In contrast to aneuploidy, euploidy has contributed very little to speciation within the genus. Chromosome number determinations for two natural hybrids of which one is considered to be the result of triple hybridization, namely, *A. cruentus* ($2n = 34$) × *A. hybridus* ($2n = 32$) = hybrid ($2n = 32$), and *A. cruentus* ($2n = 34$) × *A. powellii* ($2n = 34$) × *A. retroflexus* ($2n = 34$) = hybrid ($2n = 32$) have indicated differences in chromosome numbers between the putative parents and the hybrids. A survey of the natural interspecific hybrids reported in the literature indicates that at least half the species of the genus have been involved in hybridization. Natural interspecific hybridization and aneuploidy are considered as the major factors which have lead to species variation, speciation, and to the taxonomic complexity of the genus.

Electronic Figure Reader

The EMI Co., Ltd., has recently held a series of public demonstrations of its 'figure reading electronic device'—*Fred*. This is a relative newcomer to the field of machines which are able to read directly from printed characters; but, because it uses a specially designed type face, it is unlikely to provide a general solution to the pressing problem of direct input to data processing machines. Nevertheless, for the more limited objective of cheque sorting for the banking industry, this new British development is likely to have a considerable future, particularly in view of the fact that an accurate arrangement of the documents is unnecessary.

Science and Faith

"Questions of Science and Faith" is one of a series, "Foundations for Faith", likely to appeal to those who have reached the final stage of their school course or are in the early terms of their university studies (pp. 63. London: The Tyndale Press, 1960. 2*s*.). A short bibliography is added for any who wish to pursue the subject further. Writing as a biochemist, Dr. Hawthorne covers most of the points raised by students genuinely interested in the validity of the Christian faith. Misunderstandings are removed concerning the so-called conflict between science and religion. The Bible, creation, the origin of life, and miracles, are some of the themes included in this short survey. It is to be commended for its clarity and is a welcome addition to the growing volume of literature which seeks to view the world of science in its relation to the realm of the spirit.

Royal Meteorological Society: L. F. Richardson Prize

The Council of the Royal Meteorological Society has decided to institute a new award, to be known as the L. F. Richardson Prize, for the encouragement of research by young meteorologists. The Prize will consist of £25 together with a book, and will be awarded for meritorious papers contributed to the Society's *Quarterly Journal* by members who were under the age of twenty-eight at the time the papers were submitted for publication. It is intended that the award shall be made annually, subject to the attainment of certain standards. The full regulations for the new award will be printed from time to time in the Society's *Quarterly Journal* and in its monthly magazine, *Weather*.

Training Grants in Plastics Technology

Applications are invited from young men and women now working in the plastics industry for a limited number of training grants towards the cost of full-time study on an approved course leading to a degree, diploma or other equivalent qualification in

science or technology, or in industrial design. The grants are to be awarded by the trustees of the Plastics Industry Education Fund and will be made for periods of one year at a time. The value of the grants will normally be of the order of £100. Applications must be submitted in writing to the Secretary, Plastics Institute, 6 Mandeville Place, London, W.1, by July 15.

International Conference on High-Energy Physics

THE tenth annual international conference on "High-Energy Physics" is to be held at the University of Rochester during August 25–September 1. The Conference has been authorized by the Commission on High Energy Physics of the International Union of Pure and Applied Physics. Other sponsors are the U.S. National Academy of Sciences, the U.S. National Science Foundation, the U.S. Atomic Energy Commission, Office of Ordnance Research and a number of industrial organizations. Approximately 175 delegates from more than 30 countries will attend the conference including India, Australia, Sweden, Brazil, Pakistan, Israel, Mexico, Turkey, Yugoslavia, Argentina, Poland and Greece. The U.S.S.R. has signified its intention of sending a 40-man delegation. One of the most important aspects of the Conference will be the first official reports on activities of the new 25×10^9-eV. accelerator at the European Centre for Nuclear Research in Geneva. The chairman of the Conference is Prof. Robert E. Marshak, chairman of the Department of Physics and Astronomy, University of Rochester, and also secretary of the organizing committee, and from whom further information can be obtained.

Biology of Space Travel

THE Institute of Biology is arranging a symposium to consider various biological problems connected with space travel. It will be held during September 29–30, and the topics to be considered will include: the possible existence of some form of life on other planets; the danger of contamination of other planets and the Earth by space vehicles; effects of high and extremely low gravitational forces on the human body; the effects on man of radiation in space; maintenance of life in space ships; psychological problems connected with the choice of personnel for conditions of solitude and confinement. Further information can be obtained from the General Secretary, Institute of Biology, 41 Queen's Gate, London, S.W.7.

Announcements

THE following have been elected officers for the year 1960–61 of the Salters' Company: *Master*, Mr. R. S. H. Callingham; *Upper Warden*, Sir Alexander Todd; *Second Warden*, Mr. T. G. Hicks.

DR. W. R. AYKROYD, senior lecturer in the Department of Human Nutrition at the London School of Hygiene and Tropical Medicine, and recently director of the Nutrition Division of the Food and Agriculture Organization of the United Nations, has been made an honorary member of the American Institute of Nutrition.

THE United Nations Educational, Scientific and Cultural Organization Centre for Scientific Co-operation in Latin America, Montevideo, has issued as Vol. 4 of "Scientific Institutions and Scientists in Latin America" a list of scientific institutions of Argentine (pp. vi+136. Montevideo: Unesco, Centro de Co-operacion Cientifica para America Latina, 1959).

THE seventeenth International Congress of Pure and Applied Chemistry is to be held in Munich during August 26–29. Further information can be obtained from the secretary-general of the International Union of Pure and Applied Chemistry, Dr. R. Morf, c/o Sandoz, S.A., Basle 13.

THE fifth World Forestry Congress, organized by the Government of the United States and sponsored by the Food and Agriculture Organization, will be held in Seattle, Washington, during August 29–September 16. Further information can be obtained from Dean Hardy L. Shirley, State University College of Forestry at Syracuse University, Syracuse 10, N.Y.

DURING August 29–September 9 the "Association des Cours Internationaux de Lyophilization" will be holding the second international course on "Lyophilization" at the Institute National des Sciences Appliquées in Lyons. Further information can be obtained from Dr. Louis R. Rey, Laboratoire de Physiologie, Ecole Normale Supérieure, 24 rue Lhomond, Paris 5e.

UNDER the auspices of the International Federation of Electron Microscope Societies, the Nederlandse Vereniging voor Electronenmicroscopie is organizing a European regional conference on "Electron Microscopy". This is to be held at Delft during August 28–September 3. Further information can be obtained from A. L. Houwink, secretariat of the European Regional Conference on Electron Microscopy, Julianalaan 67a, Delft.

THE first International Pharmacological Meeting is to be held in Stockholm during August 22–25, 1961. The meeting is to be held under the auspices of the Section of Pharmacology of the International Union of Physiological Sciences. Further information can be obtained from the secretary-general, A. Wretlind, First International Pharmacological Meeting, Karolinska Institutet, Stockholm 60.

THE first International Congress of Histochemistry and Cytochemistry is to be held in Paris during August 28–September 3. The Congress is organized under the auspices of the Société Française d'Histochimie in collaboration with histochemical societies in many other countries. Further information can be obtained from the secretary-general, Dr. R. Wegmann, First International Congress of Histochemistry and Cytochemistry, 45 rue des Saints-Pères, Paris 6e.

THE Czechoslovak Academy of Science is to organize an international conference on "Semiconductor Physics" at Prague during August 29–September 2, under the auspices of the International Union for Pure and Applied Physics, and which will continue the series of conferences held in Reading (1950), Amsterdam (1954), Garmisch–Partenkirchen (1956) and Rochester (1958). Further information can be obtained from Dr. Miloš Matyáš, Institute of Technical Physics, Prague 5, Cakrovarnická 10, Czechoslovakia.

ERRATUM. Mr. M. W. Hardisty, writing with reference to the communication "Sex Ratio of Ammocoetes" in *Nature* of June 18, p. 988, states that the symbols ♂ and ♀ should be reversed.

THE DECIMAL SYSTEM IN BRITAIN

DURING the past two years, committees appointed by the British Association and by the Association of British Chambers of Commerce have been examining the merits or demerits of the adoption by the United Kingdom of the decimal system of coinage and/or the metric system of weights and measures. A joint report, to which Sir Alexander Fleck contributes a foreword, has now been issued*, based on inquiries made of some 2,000 organizations, including trade associations, chambers of commerce, individual companies, learned societies and professional institutions. The report is in four parts, examining first the question of decimal coinage and then that of the metric system. In each of these parts, earlier inquiries in the United Kingdom are reviewed, and then the implications and merits of a change are considered, the cost factors and, for the metric system, the international aspects. In the third part, the improvement of the Imperial system is discussed, and in the fourth, the educational aspects such as the problems for schools and adult education.

On all the available evidence, the Committees consider that there is a strong case for the adoption of a decimal system of coinage, and, as Sir Alexander Fleck points out, this is a policy that lies wholly within our own control to determine: no international complications are involved. The Committees found little dissatisfaction expressed with the present system of coinage in industry and commerce, but wide approval of the concept of decimal coinage. There was some disagreement as to the preferred method of decimalization, but an overwhelming wish to retain the pound sterling as the major unit. If this is accepted, the pound/mil, or pound/cent, with the cent suitably subdivided, systems appear to be the most suitable, and these systems are also the most popular. Decimalization of the coinage would be helpful by simplifying money calculations, with particular advantages in the fields of business machines and education. It is primarily a domestic question; but any system which involved abandoning the pound as the major unit might lower the status of British currency. Decimalization of the coinage would give only slight advantage in international trade, and while, so far as the Committees could ascertain, the transitional costs of decimalization would be heavy, they would not be unduly large in relation to the resources of the country and the long-term benefits that would accrue. The question should be considered on its own merits independently of the system of weights and measures, but decimalization of the coinage should precede any future plan for the adoption of the metric system.

Since the evidence before the Committees was received mainly from industry and commerce, it may not accurately reflect public opinion either on the principle or the method of decimalization. General approval and understanding on the part of the public would be essential, and the report is intended in the first place to stimulate such informed discussion. The Committees believe, however, that the time has come for a decision to be made in principle on this question, and this decision can only be made by the Government. They recommend that the Government should aim at taking an early decision in principle for or against the adoption of a decimal coinage; but that before taking such a decision further inquiries should be made, including a sounding of public opinion and efforts to inform the public on the issues involved. The Committees find that a minimum of three years notice would be required to make essential preparations for the adoption of decimal coinage, and this period of notice should provide ample time to familiarize the public with the new system.

Even more emphatically, so far as weights and measures are concerned, gradualness is the keynote of the Committees' recommendations, although they do not recommend compulsory adoption of the metric system by the United Kingdom at the present time. The metric system is already legal for most purposes in the United Kingdom, and it would be possible for adoption to proceed piecemeal on a voluntary basis. For the purpose of the inquiry the view was taken that 'adoption' of the metric system by the United Kingdom meant a general adoption over a limited term of years, at the end of which the metric system would become the generally accepted system, and the Imperial system would fall into disuse.

The Committees found that little use is made to-day of the metric system in the United Kingdom except for scientific and laboratory purposes and in a few specialist fields, particularly the pharmaceutical and optical industries and scientific instruments. There is little sign here of any significant trend towards increased use, except in manufacture for, or packing for, export to metric countries, and there is no strong feeling in industry or commerce that Britain is being adversely affected either internally or in exports to metric countries by the retention of the Imperial system. Conversely, the same appears to be broadly true of manufacturers in metric countries in their efforts to sell in non-metric countries. The Committees agreed that the question of units of weights and measures is of minor importance compared with many other factors influencing the flow of international trade. There is a majority opinion that the United Kingdom should keep in line with the Commonwealth and the United States.

Although there is general agreement on the desirability of increasing standardization, there is some divergence of opinion as to how this should be achieved. At present, there still appears to be an inadequate body of agreed international standards as between the various metric countries, and certain sections of the engineering industry hold that the United Kingdom would be ill-advised to abandon such standardization as already exists in the non-metric world. Moreover, non-metric usage exists in a few industries on a world-wide basis, for example, in the oil industry, shipping, and to a high degree in aircraft manufacture and air navigation.

Generally, it is clear that transitional costs would be very heavy in some spheres, particularly engineering, but the financial benefits are difficult to assess. Should the United Kingdom decide to adopt the metric system, at least ten and sometimes 20–30

* Decimal Coinage and the Metric System: Should Britain Change? (A joint report of Committees appointed by the British Association for the Advancement of Science and the Association of British Chambers of Commerce.) Pp. xi+107. (London: Butterworths Scientific Publications, 1960.) 7s. 6d.

years would be required for the complete change-over, and the longer the period of change-over the lower the total transitional costs. Educational benefits are real, but are not easily measurable in terms of money. The Committees stress the existence of a general feeling that the metric system will in course of time become more widely used in the rest of the world and the United Kingdom. They recommend, therefore, a regular two-yearly review by the Board of Trade in consultation with industry and commerce, and in conjunction with corresponding bodies in the Commonwealth and the United States, and paying particular attention to trends in Japan and India and the under-developed countries of Asia and Africa. These reviews should indicate what stimulus might be given to more rapid change-over to the metric system in the United Kingdom and in what sections of industry and commerce metric usage could be introduced with most benefits and the least transitional dislocations. It is suggested that there may be a case for the British Standards Institution publishing further metric standards to facilitate manufacture in metric dimensions for export.

The Committees agree that there is real advantage to be gained now by increased rationalization of the Imperial system, and they recommend that this should be further studied. This is a specialist matter for each industry ; but they suggest that all Government departments and nationalized industries could examine the practicability of eliminating intermediate units of weight between the ton and the pound avoirdupois ; alternatively, use of the cental (100 lb.) should be encouraged in place of the hundredweight, and there should be a short ton of 2,000 lb. in place of the long ton of 2,240 lb. They also recommend that the apothecaries' troy and pennyweight systems be removed from school curricula, and that the rod, pole or perch of 5½ yards and the corresponding square measure of 30¼ square yards be officially abolished, and that use of the decimalized inch in place of fractions be increased. Finally, under educational aspects, they recommend that even if no action be taken on decimal coinage or the metric system, much greater emphasis should be placed forthwith on the teaching and use of decimals and the metric system in the educational curriculum of Britain from the earliest stages. This would not only promote 'decimal thinking' at an earlier age than at present, but would also be of value to entrants into industry and commerce, where the practical use of decimals is increasing.

Appendixes to the report present extracts from evidence received on decimal coinage and the metric system, and group the countries of the world according to their adoption or not of the metric system.

SELECTION OF EXECUTIVES

DURING the years immediately after the Second World War, it was the fashion for amateur and professional psychologists to see 'significance' in a great variety of phenomena, from handwriting to the choice of a wife, from remarks made during a group discussion to readiness to become angry at an interview, from imagined shapes seen in an ink-blot to the design created with a set of mosaics. That any one of these actions can be significant of itself was an assumption which has invalidated much of the psychology of personality testing during the past ten years, and such is the subject of a recent article in the *European Productivity Agency Bulletin* (No. 34 ; February 1960).

The recent trend has been a healthy one. Amateur psychologists are not so respected in their assessment of significant revelations. Professional psychologists have considerably limited their claims and disciplined their methods, thereby increasing their effectiveness. But much indisciplined personality testing still goes on. Recently, a works manager was appointed solely on the judgment of the managing director's wife's interpretation of the applicant's handwritten signature to a typewritten letter. A brilliant technologist was rejected in favour of a less-qualified man because he did not take a lead in a discussion with other candidates during a specially organized hotel dinner. A psychiatrist employed by a large organization in London interviews candidates for the higher staff grades and deliberately sets out to anger them, judging from the time it takes them to lose their tempers whether or not they have initiative.

Warren Lamb suggests that it is an imposition to subject a candidate to having his individual actions judged as to their significance and what they reveal without being able to defend himself. The existence of significance testing is due to two fallacies underlying the most scrupulous application of pure psychological research within industry and commerce : (*a*) that a test situation can be so devised that the candidate's response will be identical with what it would be on other occasions ; (*b*) that a quality once measured (for example, dominance, perseverance) will apply in all conditions.

Validating procedures have so narrowed down the aims under (*a*) that the results of properly validated present-day performance tests are so prescribed as to make only a minor contribution to industrial selection and appraisal. The simplest of casual observation will dispose of (*b*). One would not have to search far to find the dominant business man and the submissive husband. A recent survey of top-ranking business executives in England revealed that the greatest common characteristic was extreme shyness.

Is it possible to have any form of personality testing which does not depend upon attributing significance to any one action or response ? One method has been devised based on an analysis of constant elements in a person's movements.

No two people move in exactly the same way ; in habitual adjustments of posture, gestures, handling of objects, a way of walking and so on, there are distinct individual differences. It has been found that everyone has certain movement co-ordinations which are constant to all his activities. That is to say, there are certain elements in the total movement which remain constant whatever the person's behaviour or emotion. For example, these elements will remain constant during an occasion when the person is sitting relaxed enjoying a casual conversation, and on another occasion when he is giving a demonstrative, angry, fiery political speech. Sets of observations taken on each occasion, and analysed separately, produce an identical result.

A person's movements are different on varying occasions. It is only part of his movement—a part even of each action—which remains constant. The full range of the constant elements will never be present in any one action. A large number of observations are needed, based on a statistical sampling method in order to have sufficient data to analyse. It has proved practicable to obtain this data in the course of a normal business interview.

The development of this work needed a more penetrating investigation into the details of a movement than has usually been the case with other investigations. The present methods have been made possible by the work of Rudolph Laban. The codification of the elements of movement upon which Laban established his notation has made it possible to record the process of variation of at least seven different movement components occurring simultaneously in the course of one action.

Movement analysis reveals those capabilities which can be expressed spontaneously. A person who can present himself or exercise authority spontaneously would not have to depend upon 'props' such as the correct dress or a conferred status. A distinction can be made between those whose authority is fixed, dependent upon a static set of circumstances, and who would have little range of the relevant movement variation, and those whose authority is spontaneous and adaptable, and who would have a good range of variation.

If a person is asked to perform a number of actions unassociated with any particular purpose and built up from within his range of constant elements, he enjoys the movement. If he is asked to perform actions built up from outside the range, he invariably feels awkward and unco-ordinated. Many experiments with people of many different vocations have shown this to be true. The range of constant elements is the range within which a person 'feels right'.

That there is a relationship between mental functioning and physical movement is implied in the development of psychosomatic medicine during the course of the present century.

The application of this work within industry has been on the basis that if a person is able to work within a set of conditions by meeting the needs from within his range of constant elements (that is to say, the range within which he 'feels right'), then he has aptitude for that set of conditions. This gives a precise definition to what is meant by 'aptitude', a word which is often used loosely as a synonym for ability, potentiality, capacity or even intelligence.

In order to make an 'aptitude assessment', it is necessary to specify the particular set of conditions, and this is done according to current techniques of job evaluation, differentiating between those aspects of the job which can be satisfied through purely technical competence and those aspects which can be met effectively only through the appropriate aptitude. It is obvious, but often little considered, that a man of a certain technical competence may be able to apply his skill effectively in one set of conditions and ineffectively in another. The aptitude assessment which derives from the analysis of constant elements in movement is a measure of a person's readiness to apply his technical skills or knowledge within a specified set of conditions.

Whereas much investigation of the 'significant response' type seeks to classify phenomena, reduces differences and generalizes, the methods of aptitude assessment based on movement observation follow a contrasting procedure. There is no classification of phenomena, differences are magnified, both within the individual and the conditions, and the resultant assessment is a particular yardstick, applying only within specified conditions. The procedure brings forward the exceptional, distinctive 'man of the moment', as against the average, conformist 'type for the job'.

The procedure is not itself exceptional and is akin to existing practices. An appreciation of the techniques is easily gained during practical study. A number of intensive two-week courses have successfully been given to executives wishing to incorporate the techniques within their own company practices.

T. H. Hawkins

SCOPE FOR EXPANDING PULP AND BOARD INDUSTRIES IN BRITAIN

THE conclusions and recommendations of two reports prepared by Sandwell and Co., Ltd., on pulp and board mills in Great Britain (see *Nature*, March 26, p. 894) were used as the basis of a discussion organized by the Society of Foresters of Great Britain and held during November of last year. This Society is concerned with "the knowledge of technical forestry in all its aspects" and it was fitting that on this, the first, of its ventures into special discussion meetings it decided to examine the implications of the Sandwell reports. The proceedings of this meeting have now been published as a supplement to the Society's journal, *Forestry*, which is available to non-members*. The programme was designed to give a balanced picture of the problems involved in development and the individual views of industrialists, technologists, and competitors for the wooden raw material. The growers' point of view was discussed under forest management considerations and the whole idea was subjected to the economist's evaluation, and a careful summing up.

As the Society of Foresters of Great Britain included few industrialists in its membership, invitations were sent to leading personalities in the industries concerned. Dr. T. H. Frankel, of Sudbrook Pulp Mill, Ltd., a subsidiary of Wiggins Teape and Co., Ltd., said that in his view the Sandwell reports implied that the smaller the mill the less efficient it would be. In exploring the possibility of setting up a pulp mill in the Scottish Highlands, he stressed the unlikelihood of a newsprint mill being sited in Britain. He examined some of the technical and economic problems of the industry and urged that the criterion for growers of timber should be to produce the maximum bone-dry weight, bark free, per acre per

* The Development of Pulp and Particle Board Industries and Their Effect on Forest Management. Pp. 68. (Oxford University Press, 1960.) 5s.

annum. The development of the chipboard industry was reviewed by Mr. F. C. Lynam, of Airscrew Co. and Jigwood Ltd., who criticized the Sandwell Board Mill Survey because it did not do justice to the possibilities of development. Its most important conclusion, he believes, is that even in a large plant the economic price would have to be about £11–£12 per ton of bone-dry wood. Mr. B. J. Rendle, of the Forest Products Research Laboratory, and Dr. L. Chalk, of the Department of Forestry, University of Oxford, explained the anatomical criteria for industrial use and the problem of 'juvenile' wood, respectively. If it were known what the pulp mills would like to have, this could be taken into account in plans for improving trees by selection and breeding and by forest management. The problem of 'juvenile wood' is often over-simplified, especially by the assumption that it is a matter of age.

The requirements for the coal mining industry were reviewed by Mr. B. C. Hollingsworth, of the National Coal Board, who explained that the Board has followed a policy of purchasing home-grown timber, of which it has greatly increased its consumption since 1947 and still has room for increased softwood demand. Rising production from thinnings may well meet the needs of the pulp and of the coal industries, and the arrival of a new market for the raw material would solve problems and confer benefits on all consumers as well as on producers. The prospects of greater demand from the furniture industry were explored by Mr. J. P. Pritchard, of the Furniture Development Council. In his opinion there are several ways in which growers and chipboard manufacturers could help to raise the demand for their products. The industry was progressive and expanding, like the size of the firm, thus making possible greater expenditure on design and development. As a consultant in wood technology, Dr. S. E. Wilson, who is well placed to examine the needs for housing and packing, declared that the principal aim of domestic forests in Britain has been, and still was, to supplant the imported deals, battens and boards used mainly in the building and packaging trades.

The Forestry Commission's director of forestry for England, Mr. G. B. Ryle, questioned the view that in Britain we should be justified in running our forests primarily for the pulp and board industries. Forest management, he said, implied three things in this context: the right trees for the industry; the optimum rate of growth and right specifications and operational efficiency.

The evaluation of the economists was provided by Mr. G. W. Troup, of Albert E. Reed and Co., Ltd. He said that he could not give the final answers on the prospects for small-scale pulping in Britain—about which the Sandwell reports had been rather discouraging—but he did suggest some of the questions which remained for investigation, for example, on such matters as roundwood yields and price and costs trends. One of the interesting points emphasized in the economics discussion was that the 'Outer Seven' proposals have no bearing on pulp mills, although they will affect board mills because the existing tariff protection will be gradually reduced over, at the most, ten years. This will almost certainly lead to greater integration in the pulp and paper and board industries, for example, in the Scandinavian countries, and thus add to the competitive power of imported supplies.

Many searching questions and observations were a feature of the seven discussions which followed the main papers, and many leading authorities among the members and guests of the Society of Foresters were asked to open the discussions in a formal and thorough fashion. It was held by Mr. K. N. Rankin, of the Economic Forestry Group, when he summed up what had emerged from the meeting, that there is a clear need for all to see themselves as one industry—growers, saw-millers, and processors. There is need for over-all planning as one industry and for the utmost efficiency in all sectors in order to be competitive by world standards. The objects of the planning should be 100 per cent utilization of forest products and the highest return on the capital employed in the industry. With these objectives in mind, Mr. Rankin went on to suggest what kind of pattern production should follow. Pulp and paper demand is rising at 7 per cent per annum and if supplies cannot keep pace there is a fair prospect of rising prices. The directions in which growers could more satisfactorily produce what is wanted was also reviewed in some detail. Mr. Rankin ended with the challenging questions: Why should we not export more timber products and why should we not have vertical as well as horizontal integration in the industry?

J. J. MacGregor

ATOMIC ENERGY RESEARCH IN DENMARK

THE third annual report of the Danish Atomic Energy Commission describes the activities of the organization during the period April 1, 1958–March 31, 1959 (pp. 85. Copenhagen: Danish Atomic Energy Commission, 1959). It deals with the erection of the Risø Research Establishment; the reactors *DR*1, *DR*2 and *DR*3; the work of the six departments of the Establishment; international co-operation in the peaceful uses of atomic energy through the International Atomic Energy Agency, the Organization for European Economic Co-operation and the European Atomic Energy Society; and includes the texts of the addresses delivered by Mr. Viggo Kampmann, Minister for Finance, and by Prof. Neils Bohr, the president of the Commission, at the inauguration of the Establishment on June 6, 1958.

During the period under review the Commission met seven times and its executive committee thirty-three times. Prof. Neils Bohr continued as chairman of the Commission, with Dr. H. P. Christenson as vice-chairman, and H. H. Koch as chairman of the executive committee. The total staff on March 31, 1959, numbered 385, of which 214 were employed in the technical and scientific division and distributed over the six departments. The secretariat, headed by the chief of Commission secretariat, had a staff of twenty-six, including three law and one economics graduates. The office of the Commission was at the Christiansborg Palace, but the secretariat had a subsidiary office at Risø.

The physics department of the Establishment consists of the physics laboratory, the meteorology

station and the reactor *DR*1. During the year a cooling system for the reactor was installed, and the power brought up to 1,100 W. Various technical measurements were carried out on the reactor, and training procedures and instructions for courses were revised and improved. The solid-state group continued work on instruments for the study of radiation damage to metals and graphite, and other groups were occupied with planning a new laboratory and its equipment in connexion with the linear accelerator ordered from the United States and with the assessment of the energy and particle balance in a very hot hydrogen plasma.

In the electronics department an analogue computer, the equipment for a 'gas-flow' proportional counter for use at the waste-water treatment plant at Risø, and a fluorimeter for the measurement of uranium content in samples with concentrations of about 10^{-6}, in addition to a number of special pieces of apparatus, have been constructed. The work of the reactor engineering department was largely concentrated on the study project for the heavy-water-moderated power reactor with an organic cooling medium to be known as *DOR*. The department has been concerned also with constructional and safety problems related to reactor-powered ships.

In addition to its direct educational and training activities in technical and scientific subjects, the report states that the Commission tries to satisfy general public interest in nuclear energy and in the Research Establishment by publications, radio and television broadcasts and exhibitions. A documentary film about Risø is being prepared. Visits to the Establishment are limited to Saturdays, and during January 1–March 31, 1959, about 1,200 persons visited Risø.

The report concludes with a list of the publications by members of the staff of the Commission, and with a detailed map of the layout at the Research Establishment.

AGE OF THE BASE OF THE CAMBRIAN

In a recent publication[1], Prof. Arthur Holmes has proposed a revision of his 1947 time-scale. This revision was necessitated by the wealth of new age measurements made since 1947, and it is a tribute to Prof. Holmes's insight that his first time-scale, proposed in 1911 when the science of geochronology was in its infancy, has required only relatively minor revisions since that time. In view of Prof. Holmes's past successes in drawing correct conclusions from fragmentary data, it might seem unwise to question his present conclusions regarding the age of the base of the Cambrian system. Furthermore, it is true that imaginative speculation frequently proves more fruitful than sterile scepticism. Nevertheless, in this case, I feel that a critical discussion of the grounds for fixing the age of the base of the Cambrian is in order in the hope that workers may recognize that a problem exists. Otherwise the figure 600 ± 20 million years may prematurely find its way into texts and into the minds of Earth scientists as an established fact of geology.

At the outset, it must be realized that the concept of the base of Cambrian is different from that of the base of the other periods. The base of the Devonian, for example, is defined by the disappearance of characteristic Devonian fossils as one moves down the column and by the appearance of Silurian fossils. In contrast to this, the base of the Cambrian is either defined locally as an unconformity beneath strata containing Cambrian fossils or by the failure to discover lower Cambrian fossils in lower strata. In the first case, there is no reason at all for the local unconformity to have world-wide time significance, and in the latter case, the evidence is of necessity purely negative ; the apparent absence of a Cambrian fauna may be due to causes other than age. For purposes of discussion, it is more useful to fix some definable horizon within the Cambrian, for example, the base of the Middle Cambrian and at least for some purposes mentally lump the Lower Cambrian with the Precambrian. This point of view does not significantly alter the discussion of the evidence cited by Holmes ; it merely sharpens the definitions employed. This approach relegates to future research such difficult questions as the time of the first appearance of *Olenellus* and its simultaneity in various regions of the Earth. It will be shown that the data used by Holmes do not yield a firm upper limit to the age of the base of even the Middle Cambrian, and it therefore follows that they do not permit an upper limit to the age of any part of the Lower Cambrian, however it may be defined. (In order to avoid any ambiguity it should be pointed out the expression 'an upper limit to the age' is used to mean that the age is less than a certain number of years. In this expression the word 'upper' is therefore used in a numerical, not a stratigraphical, sense.)

The principal data used by Holmes in placing an upper limit to the age of the base of the Cambrian are those of Kulp (reported by Campana[2]) and Greenhalgh and Jeffery[3] for absite from pegmatites overlain by the Precambrian Adelaide System in South Australia. Since the Adelaide System lies below recognized Lower Cambrian strata, it is clearly pre-Middle Cambrian.

These authors report ages in million years as follows:

	$^{206}Pb/^{238}U$	$^{207}Pb/^{235}U$	$^{207}Pb/^{206}Pb$	$^{208}Pb/^{232}Th$
J. L. Kulp	520	600	915	585
Greenhalgh and Jeffery	610	674	895	675

Following Greenhalgh and Jeffery, Holmes interprets these data as a "typical loss of radon pattern", and in accordance with this a probable age of 674 million years is assigned to the sample analysed by Greenhalgh and Jeffery, with 915 million years considered an improbably high upper limit. However, it should be pointed out that there is no age pattern for a single mineral which is diagnostic of loss of radon. There are two independent uranium–lead ages, that calculated from the ratio lead-206/uranium-238 and that calculated from the ratio lead-207/uranium-235. In the data under consideration, the former age is younger than the latter, and this pattern can arise equally well from any of several mechanisms, namely, preferential loss of lead relative to uranium, additions of uranium, gain of radiogenic

lead of some isotopic compositions, or preferential loss of an intermediate daughter product of the uranium-238 series, for example, radon. By simply examining the pattern of discordant ages one can never distinguish between these possibilities. The relative importance of the different possible causes of discordance must be evaluated by independent methods. I am not aware of any experimental data for absite, but measurement of the radon-loss from minerals possessing reasonably well-defined crystal structures has shown such loss to be of minor importance[4,5]. In contrast to this, there is abundant evidence from intercomparison of uranium–lead ages with ages measured by other methods that loss of radiogenic lead or, equivalently, gain of uranium, is a common cause of discordance in uranium–lead ages. If this more common process is responsible for the discordant data on the sample in question, the limit of 915 million years is a lower limit to the age rather than an improbably high upper limit. The lead-208/thorium-232 age contributes little to the argument since for unknown reasons these ages are almost always badly discordant.

Greenhalgh and Jeffery also report a potassium–argon age of 520 million years on a sample of biotite from the same rock. Even if one postulates loss of radon as the cause of discordance, this result cannot be reconciled in any simple way with the absite data. Taken altogether, the absite and biotite data indicate that for some reason the minerals in question have been open with respect to either the parent or daughter elements, or both, since the time of their original crystallization and their apparent ages are scarcely suitable for fixing a critical point in the geological column.

Some further data bearing on this matter are the results of measurements of Tilton *et al.*[6] on igneous rocks in the Wichita Mountains of Oklahoma. As pointed out by Holmes, the result of 500–550 million years places at best a limit on the age of a portion of the Upper Cambrian, since there are no Middle or Lower Cambrian strata in the region. It should be further noted that the granitic samples which have been dated are not seen in actual contact with the Cambrian strata and the inference that they are pre-Upper Cambrian is based on the assumption that they are the same age as the neighbouring Carlton rhyolite which is actually overlain by Reagan sandstone of Upper Cambrian age, or on the correlation of these rocks with pre-Reagan granites found in sub-surface drillings.

The remaining evidence cited by Holmes is that based on analysis of uraninite from Katanga, Belgian Congo. The results of age measurements of these samples are reasonably concordant and indicate an age of about 625 million years for the uranium mineralization. As quoted by Holmes, L. Cahen states that the uranium mineralization is later than the Kundelungu formation, which is assigned to the Precambrian by the absence of Cambrian fauna and by the presence of 'Late Precambrian' fossils. Cahen further concludes, as is necessary for the argument, that we can dismiss the idea that the Kundelungu sediments are much older than the uraninites. While this is the best evidence given by Holmes for saying that the age of the base of the Middle Cambrian is less than 600 million years old, the evidence is obviously not clear-cut, in view of the dubious status of Precambrian palæontology and the uncertainty in the inference that the uranium mineralization does not greatly post-date the Kundelungu sedimentary rocks. It would be of considerable interest if Dr. Cahen would discuss critically the reasons for his opinions quoted above and by Holmes.

These remarks have been made with the hope of acquainting workers both in the field of geochronology and stratigraphy with this unsolved problem. A start might be made by demonstrating unequivocally that the base of the Middle Cambrian is less than 1,000 million years old. Rocks of this age are found in many parts of the world, but I do not know of any localities where the relationship of dated rocks of this age to the Cambrian is clearly established. If the possibility that rocks of Grenville age (1,000 million years) and their age equivalents in other regions are Upper or Middle Cambrian can be definitely excluded in this way, then one may go to the rarer areas of rocks in the 600–900 million years age-range in order to see if more strict limits can be obtained.

G. W. Wetherill

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[1] Holmes, A., *Proc. Edin. Geol. Soc.*, **17**, 183 (1959).
[2] Campana, B., *Austral. J. Sci.*, **16**, 240 (1954).
[3] Greenhalgh, D., and Jeffery, P. M., *Geochim. et Cosmochim. Acta*, **16**, 39 (1959).
[4] Giletti, B. J., and Kulp, J. L., *Amer. Mineralogist*, **40**, 481 (1955).
[5] Starik, I. E., *Geokhimiya*, No. 5, 18 (1956).
[6] Tilton, G. R., Davis, G. L., Wetherill, G. W., and Aldrich, L. T., *Trans. Amer. Geophys. Union*, **38**, 360 (1957).

While in principle I am in general agreement with Dr. Wetherill, I feel that he over-rates some of the difficulties to which he refers and exaggerates their geochronological consequences.

The "base of the Cambrian" is not a natural phenomenon that can be discovered and objectively investigated. It is a mental concept, entirely dependent on definition and, until agreement is reached, subject to argument and dispute. Geologists are still actively discussing whether the criteria for defining it should be: (*a*) palæontological, for example, the first appearance of the earliest trilobites or of other fossils elsewhere associated with them; (*b*) stratigraphical, for example, the first deposits of the corresponding marine transgression; (*c*) palæoclimatological, for example, tillites and other evidence of the glaciations commonly regarded as having occurred towards the close of the pre-Cambrian; or (*d*) geochronological, a hope for the future which may eventually command widespread assent[1]. Meanwhile, most geologists consider (*b*) and (*c*) to be inappropriate because the events concerned are likely to have varied from place to place much more widely in time than the appearance of the earliest Cambrian fauna. Adopting the "lowest formation in which the biozone of *Olenellus* or its equivalent is represented" as the base of the Cambrian, I found 600 ± 20 million years to be "a reasonable estimate" for the beginning of the Cambrian Period in the light of the evidence then available[2]. Surely this is neither "imaginative speculation" nor "fixing the age". I see no reason why any geologist, however naïve, should suppose the figure provisionally adopted to be "an established fact". However, referring to "Earth scientists", Dr. Wetherill thinks otherwise, and in so far as there are now many Earth scientists who are not geologists he may be right. If so, his warning to them will serve a very useful purpose.

With regard to the age pattern for the South Australian absite (Greenhalgh and Jeffery's data) it

is true, as Dr. Wetherill points out, that it could arise from a variety of different mechanisms, among which he seems to favour loss of lead and/or gain of uranium. In this case, 895 million years would approximate to the real age, leaving the lead-208/thorium-232 age to be regarded as wrong. In contrast, I was impressed by the equality of the lead-208/thorium-232 and lead-207/uranium-235 ages (675 and 674 million years, respectively), particularly because this coincidence means that all four 'ages' can be brought into concordance by the single assumption of loss of radon. Greenhalgh and Jeffery[3] say: "One might expect some radon loss in a mineral such as this absite which has been situated in a porous shear zone since its formation in Upper Proterozoic times". If this be the correct interpretation, loss of argon from biotite would be expected to be even greater. The argon-40/potassium-40 age of 520 million years found by Greenhalgh and Jeffery for biotite from the same rock is readily accounted for by loss of argon and is therefore not so irreconcilable with the absite data as Dr. Wetherill supposes.

However, this disagreement over the interpretation of inconclusive data is of minor significance in the light of the age determinations of Lower Cambrian and Late Precambrian glauconites summarized on p. 195 of my paper[2]. Working at the Massachusetts Institute of Technology, Cormier obtained a rubidium/strontium age of 584 ± 30 million years for glauconite from a sandstone in the Murray Shale formation of Blount Co., Tennessee. It is notable that the first diagnostic Lower Cambrian fossils appear in shales 500 ft. higher up in the section. This result agrees closely with the argon-40/potassium-40 ages of Lower Cambrian glauconites which have been dated by Russian workers. One particularly valuable set of results refers to drill-cores from the Serdobskaya Borehole *R*-2, which passes through flat-lying Lower Cambrian strata and penetrates well into the Late Precambrian formations of the Upper Sinian, which are also flat-lying. Here, in the central part of the Russian Platform, which has long remained undisturbed by igneous or tectonic activities other than gentle vertical movements, only a slight disconformity separates the Cambrian from the Sinian. There could scarcely be a better environment for the retention of radiogenic argon. The age determinations, summarized in Table 1, have been recently revised by Polevaya, Kazakov and Murina[4], using $\lambda_e = 0{\cdot}557 \times 10^{-10}$ yr.$^{-1}$ and $\lambda_\beta = 4{\cdot}72 \times 10^{-10}$ yr.$^{-1}$ for the age calculations. In the last column the ages are recalculated with $\lambda_e = 0{\cdot}585 \times 10^{-10}$ yr.$^{-1}$ to correspond with current American and British practice.

Table 1

	Depth from surface	$^{40}Ar/^{40}K$	Ages in m.y. (± *c.* 10%) P., K. and M.[4]	Re-calculated
Lower Cambrian	1,380 m.	0·0398	606	566
Disconformity	1,630			
Upper Sinian	1,758	0·0499	734	692
	1,787	0·0499	732 } 743	692 } 701
		0·0515	753 }	710 }

Dating of these specimens by the rubidium/strontium method is in progress and it may reasonably be hoped that Dr. Wetherill's doubts will be resolved during the next two or three years. Perhaps even better evidence may be forthcoming from the dating of Lower Cambrian and Late Precambrian lavas. Here a start has already been made, stimulated by the International Geochronological Conference organized by the New York Academy of Sciences in March, and likely to be still further advanced as a result of the discussions of the Cambrian/Precambrian problem which are scheduled for the forthcoming meetings at Copenhagen of the International Geological Congress.

Arthur Holmes

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[1] "Les Relations entre Précambrien et Cambrien" (Colloques internationaux 76, Centre National de la Recherche Scientifique. Paris, 1958).
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NUCLEAR FISSION IN THE EARLY HISTORY OF THE EARTH

By Prof. P. K. Kuroda

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It has long been speculated that at least part of the heavier isotopes of xenon in the Earth's atmosphere are fissiogenic[1-3]; but it was not possible to treat this problem on a quantitative basis until Reynolds[4] showed that the abundance ratio of the stable xenon isotopes in the Richardton meteorite was different from that in the Earth's atmosphere[5].

The difference indicates that at least 10 per cent of the atmospheric xenon-136 is fissiogenic. This is much greater than that expected from the uranium-238 spontaneous fission alone, but can be explained as due to the spontaneous fission of some of the extinct trans-uranium elements and/or the induced fission of uranium-235 in the early history of the Earth. The contribution from the natural fission processes is estimated to be at least 10^6 times that from the recent artificial nuclear explosions.

Differences in the isotopic rations of xenon in the Earth's atmosphere and in the meteorite may be written as:

$$\delta_i = \left(\frac{Xe^i}{Xe^{130}}\right)_T - \left(\frac{Xe^i}{Xe^{130}}\right)_M \qquad (1)$$

where Xe^{130} is used as a reference standard for the following reasons: (*a*) the abundance of this nuclide is fairly large, and hence the errors in the mass-spectrometric measurements are expected to be small; (*b*) it is shielded by tellurium-130 (the half-life for the double β-decay of tellurium-130 was estimated by Inghram and Reynolds[6] to be $1{\cdot}4 \times 10^{21}$ years), and the amount produced by fission can be regarded as negligible; (*c*) possibility of the production of this nuclide by other nuclear reactions appears to be comparatively small[6].

Table 1. Comparison of the Isotopic Compositions of Xenon in the Atmosphere and in the Richardton Meteorite

Mass No. (i)	Atmosphere $(Xe^i/Xe^{130})_T$	Meteorite $(Xe^i/Xe^{130})_M$	δ_i	Δ_i
124	0·024 ± 0·000	0·035 ± 0·004	−0·011 (±0·004)	−0·0005
126	0·022 ± 0·000	0·029 ± 0·004	−0·007 (±0·002)	−0·0003
128	0·470 ± 0·003	0·528 ± 0·082	−0·058 (±0·085)	−0·0002
129	6·47 ± 0·06	9·18 ± 0·29	−2·71 (±0·35)	−0·02
130	1·000 ± 0·000	1·000 ± 0·000	0·000	0·000
131	5·18 ± 0·05	5·05 ± 0·17	+0·13 (±0·22)	+0·01
132	6·58 ± 0·05	6·15 ± 0·16	+0·43 (±0·21)	+0·03
134	2·56 ± 0·01	2·40 ± 0·06	+0·16 (±0·07)	+0·02
136	2·17 ± 0·01	1·98 ± 0·03	+0·19 (±0·04)	+0·03

The values of δ_i calculated from the data by Reynolds[4] and Nier[5] are shown in Table 1.

The large negative value of δ_i for xenon-129 is due to the decay:

$$I^{129} \xrightarrow{1{\cdot}7 \times 10^7 \text{ yr.}} Xe^{129}$$

as pointed out by Reynolds[4]. The small negative values of δ_i for the lighter isotopes are probably due to mass fractionation or cosmic-ray-induced nuclear reactions.

Suess[7] derived the following equation which correlates the ratio of the terrestrial abundance ($N_{\text{ter.}}$) and the cosmic abundance ($N_{\text{sol.}}$) of the rare gases with the mass (M/m_1):

$$-\log \frac{N_{\text{ter.}}}{N_{\text{sol.}}} = 10 \cdot e^{-0.045 M/m_1} + 7{\cdot}1 \qquad (2)$$

Differences (Δ_i) in the isotopic ratios of xenon in the Earth's atmosphere and the cosmic abundance ratios $(Xe^i/Xe^{130})_C$:

$$\Delta_i = \left(\frac{Xe^i}{Xe^{130}}\right)_T - \left(\frac{Xe^i}{Xe^{130}}\right)_C \qquad (3)$$

can be calculated from equation (2).

The values of Δ_i thus calculated are shown in column 5 of Table 1.

It is interesting to note in Table 1 that the values of δ_i and Δ_i vary in the same direction; but the absolute value of δ_i is always much greater than that of Δ_i, suggesting that the effect of the mass fractionation is probably small.

A maximum contribution from the uranium-238 spontaneous fission can be calculated from the terrestrial abundance ratio of uranium to xenon. The number of atoms of Xe^i produced by the uranium-238 spontaneous fission is:

$$(Xe^i)_f = \frac{\lambda_f}{\lambda_a + \lambda_f} (U^{238}) \left[\exp\{(\lambda_a + \lambda_f)T\} - 1\right] . Y_i \qquad (4)$$

where λ_a and λ_f are the decay constants for the alpha decay and the spontaneous fission of uranium-238, respectively, (U^{238}) is the number of atoms of uranium-238 in the system, Y_i is the fission yield for Xe^i, and T is the age of the system.

From equations (1) and (4):

$$\delta_i = \left[\left\{\frac{(U^{238})}{(Xe^{130})}\right\}_T - \left\{\frac{(U^{238})}{(Xe^{130})}\right\}_M\right] \cdot \frac{\lambda_f}{\lambda_a + \lambda_f} \cdot \left[\exp\{(\lambda_a + \lambda_f) T\} - 1\right] . Y_i \qquad (5)$$

Damon and Kulp[8] found that the present rate of escape of helium-4 and argon-40 from the Earth's crust is far too small to account for the quantity of argon-40 in the atmosphere, and concluded that most of the argon-40 was introduced into the atmosphere in the first billion years of Earth history from the mantle and crust. The positive values of δ_i for the heavier isotopes of xenon indicate that the uranium/xenon ratio in the meteorite system is smaller than that in the terrestrial system and hence:

$$\delta_i < \left\{\frac{(U^{238})}{(Xe^{130})}\right\}_T \cdot \frac{\lambda_f}{\lambda_a + \lambda_f} \left[\exp\{(\lambda_a + \lambda_f)(4{\cdot}5 \times 10^9)\} - \exp\{(\lambda_a + \lambda_f)(3{\cdot}5 \times 10^9)\}\right] . Y_i \qquad (6)$$

From the total amount of uranium in the crust and in the mantle (1·3 p.p.m. uranium in the crust and 0·01 p.p.m. uranium in the mantle; mass of crust = $23{\cdot}7 \times 10^{24}$ gm.; mass of mantle = $4{,}060 \times 10^{24}$ gm.) and the number of atoms of xenon in the atmosphere = $8{\cdot}14 \times 10^{36}$, given by Damon and Kulp, we have from equation (6), $\delta_i < 0{\cdot}004$ for xenon-136. (Damon and Kulp gave a range of 0·01–0·1 p.p.m. for uranium in the mantle; but in view of the recent data obtained by Hamaguchi, Reed and Turkevich[9], which indicate that older analyses for uranium were generally too high, the lower value 0·01 p.p.m. uranium was accepted.)

The observed value of $\delta_i = 0{\cdot}19 \pm 0{\cdot}04$ for xenon-136 is much greater than the calculated maximum contribution from the uranium-238 spontaneous fission, thus indicating that the uranium-238 spontaneous fission alone could not have caused such

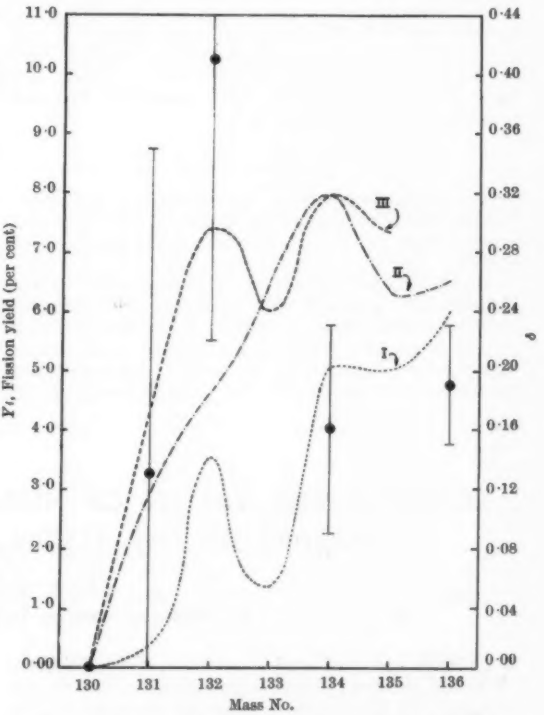

Fig. 1. Comparison of the value of δ_i with the mass-yield curves for various types of fission. I, uranium-238 spontaneous fission; II, uranium-235 neutron-induced fission; III, curium-242 spontaneous fission

The mass-yield curve for uranium-235 neutron-induced fission was taken from the report by Katcoff (ref. 18), that for curium-242 spontaneous fission was taken from the data by Steinberg and Glendenin (ref. 19), and that for uranium-238 spontaneous fission was constructed from the xenon data by Wetherill (ref. 13) and from the iodine data by Kuroda, Edwards and Ashizawa (ref. 10) and Ashizawa and Kuroda (ref. 11)

a large difference in the xenon-136/xenon-130 ratio between that in the atmosphere and in the meteorite.

The values of δ_i are plotted in Fig. 1, together with the mass-yield curves for the spontaneous fission of uranium-238 and curium-242, and also for the neutron-induced fission of uranium-235.

The mass-yield curve thus obtained from the values of δ_i differs from that for the uranium-238 spontaneous fission in that the fission yield at mass 132 seems to be abnormally high. The presence of a peak at mass number 132 in the mass-yield curve for uranium-238 spontaneous fission was found by Kuroda *et al.*[10,11]. It is interesting to note a similar peak in the curium-242 spontaneous fission mass-yield curve. This leads to a speculation that the abnormally high yield at the mass 132 might be due to the spontaneous fission of some of the extinct trans-uranium elements.

The only known trans-uranium element, which might have been present in an appreciable quantity in the early history of the Earth is plutonium-244. The half-life of plutonium-244 (8×10^7 years) is not too short as compared with the time-interval between the formation of the element and that of the Earth.

If it is assumed that plutonium-244 and uranium-238 were formed in equal abundance at the time of formation of the element, then the plutonium-244/uranium-238 ratio at the time of the formation of the Earth would have been approximately 0·05.

The ratio of the α-decay half-life and the spontaneous fission half-life of plutonium-244 is $8 \times 10^7 / 2{\cdot}5 \times 10^{10} = 3{\cdot}2 \times 10^{-3}$, while that of uranium-238 is $4{\cdot}5 \times 10^9 / 8{\cdot}0 \times 10^{15} = 5{\cdot}6 \times 10^{-7}$. Thus, the ratio of the contributions from plutonium-244 and uranium-238 is calculated to be :

$$\frac{0{\cdot}05 \times 2 \times 3{\cdot}2 \times 10^{-3}}{5{\cdot}6 \times 10^{-7}} = 570$$

or the contribution from the plutonium-244 spontaneous fission would have been several hundred times greater than that from the uranium-238 spontaneous fission.

Another important source of contribution to the atmospheric inventory of xenon is the neutron-induced fission of uranium-235. It has been pointed out by Kuroda[12] that an assemblage of uranium and water could have easily become a self-supporting chain-reacting system in the early history of the Earth. The ratio of induced fission versus spontaneous fission in some of the pitchblende ores is known to be as high as 30–50 per cent[13–15]. Kenna and Kuroda[16] have recently estimated from the radiochlorine data that the ratio in Belgian Congo pitchblende is 50 ± 5 per cent. Considering the fact that the age of the pitchblende is only about 500 million years, it is quite reasonable that the ratio in such uranium ore deposits could have been much greater than unity in the early history of the Earth.

In connexion with the contribution of uranium-235 induced fission, it is of some interest to compute the contribution from the recent nuclear bomb tests. According to Libby[17], the estimated total stratospheric injection of strontium-90 since 1952 is 66 megaton-equivalents, which correspond to an addition of about 0·5 ton of xenon-136. The total inventory of fissiogenic xenon-136 in the atmosphere is calculated to be of the order of 10^6 ton, or at least one million times greater than the contribution from nuclear bomb tests.

This work was supported by the U.S. Atomic Energy Commission. I am grateful to Prof. Edward Anders of the University of Chicago for his valuable suggestions and encouragement.

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GLUCOSAMINE VALUES OF MURAMIC ACID AND OTHER AMINO-SUGARS BY THE ELSON AND MORGAN METHOD

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WHEN muramic acid is determined by the Elson and Morgan method as described by Rondle and Morgan[1], its glucosamine value on an equal weight basis (light absorption at 530 mμ of the coloured derivative divided by that of the derivative formed from an equal weight of glucosamine multiplied by 100) is about 30 per cent[2]. If 0·5 *N* sodium carbonate used in this method is replaced by a buffer containing equal volumes of *M* sodium carbonate and *M* sodium bicarbonate *p*H 9·6[3], other conditions being the same, a glucosamine value of about 50 per cent is obtained[4]. Crumpton[3] has pointed out that glucosamine values for mannosamine and galactosamine reported by different laboratories vary significantly, presumably due to variations in the method of estimation. In my experience such values are reproducible within the limits of error of the method, and the use of a predetermined value is not likely to introduce serious errors when conditions of analysis are kept constant. However, pure samples of certain amino-sugars are not always available and this leads to the use of independently reported figures. Errors will arise if

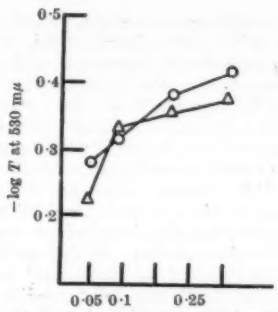

Fig. 1. Absorption values at 530 mμ of the coloured derivatives obtained in the Elson and Morgan reaction from 100 μgm. muramic acid (○) and 60 μgm. glucosamine hydrochloride (△) when the concentration of buffer salts present during reaction with acetylacetone is increased

the concentration of an amino-sugar as glucosamine determined using one set of conditions is converted to concentration of specific amino-sugar by means of a factor determined using different conditions.

Solutions containing weighed quantities of crystalline muramic acid, galactosamine hydrochloride and glucosamine-6-phosphate were determined by three modifications of the original Elson and Morgan method. The methods were : (1) according to Rondle and Morgan[1] ; (2) as for (1), but a buffer containing equal volumes of *M* sodium carbonate and *M* sodium bicarbonate, *p*H 9·6[2] was used in place of 0·5 *N* sodium carbonate ; (3) as described by Boas[3] (2 ml. of sample heated with 1 ml. *N* sodium carbonate containing 2 per cent (v/v) acetylacetone for 45 min. at 90° C.). Each amino-sugar was tested in triplicate by these methods, the average of the spectrophotometric readings at 530 mμ being compared with that given by an equimolar solution of glucosamine hydrochloride. With the exception of muramic acid[4], the coloured derivatives absorbed most strongly when light with a wave-length near 530 mμ was used. In all cases the glucosamine value varied with the method used, results for muramic acid being 48, 75 and 34 per cent with (1), (2) and (3) respectively (Table 1). The difference in results obtained with methods (1) and (2) was not due to difference in the *p*H value of the reaction mixtures containing acetylacetone for this was nearly the same (*p*H 9·5–9·6). Nor was there a significant change in *p*H in either case during heating for 20 min. at 100° C. Therefore, the only difference was the composition and concentration of the alkaline salts present. When the final concentration each of sodium carbonate and sodium bicarbonate was varied from 0·042 to 0·25 *M*, acetylacetone concentration being kept constant, the amount of coloured derivative formed with Ehrlich's reagent increased with increasing buffer concentration, particularly in the case of muramic acid (Fig. 1). The *p*H values of the reaction mixtures decreased as the buffer salts were reduced, but this was probably significant only in the case of the lowest concentration.

The lowest result for muramic acid, obtained using the Boas method, could not be due to the alkaline salt concentration, for this was twice that used in method (1). Here the *p*H value of the solution during reaction with the same concentration of acetylacetone as used in (1) and (2) was near 10, and it was shown that *p*H is an important factor by the following experiment : buffers of *p*H 8·8, 9·1, 9·6 and 9·8 were prepared by mixing appropriate volumes of *M* sodium carbonate and *M* sodium bicarbonate. Acetylacetone (2 per cent v/v) was added to each buffer (which reduced the *p*H values in all cases) and the resulting solutions were used in the determination of equimolar amino-sugar solutions according to method (1). Figs. 2 and 3 show how the amount of chromogen produced and the glucosamine values for each amino-sugar depended on the *p*H of the buffer used. Glucosamine values for muramic acid were 160 and 64 per cent when buffers with initial *p*H values

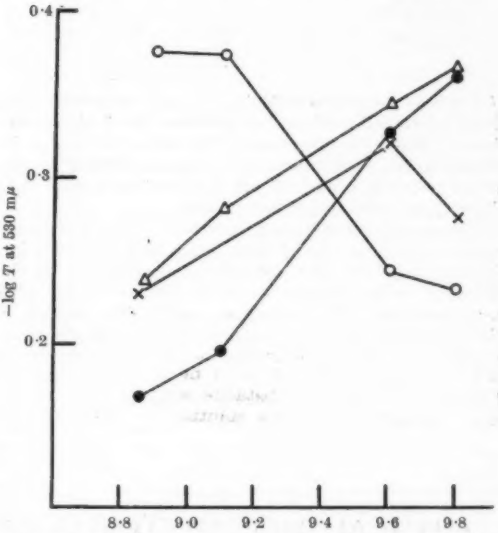

Fig. 2. Absorption values at 530 mμ of the coloured derivatives obtained in the Elson and Morgan reaction from equimolar solutions of amino-sugars when the *p*H of the buffer present during reaction with acetylacetone is increased. ○, Muramic acid ; ●, glucosamine-6-phosphate ; ×, galactosamine hydrochloride ; △, glucosamine hydrochloride

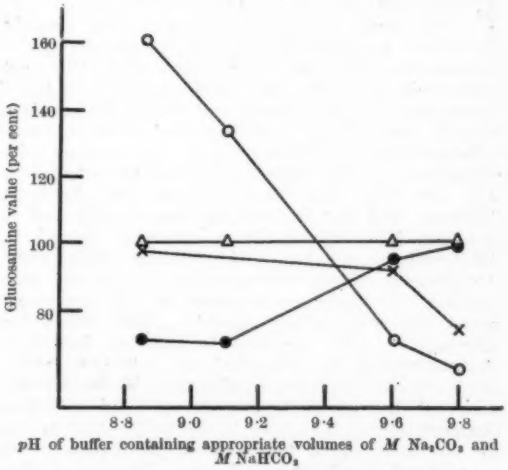

Fig. 3. Glucosamine values for equimolar solutions of amino-sugars calculated from the data given in Fig. 2. ○, Muramic acid ; ●, glucosamine-6-phosphate ; ×, galactosamine hydrochloride ; △, glucosamine hydrochloride

Table 1. Glucosamine Values for Equimolar Solutions of Amino-sugars determined by Three Modifications of the Elson and Morgan Method

Method	Per cent (at 530 mμ)			
	Muramic acid	Glucosamine-6-phosphate	Galactosamine hydrochloride	Glucosamine hydrochloride
(1) Rondle and Morgan (ref. 1)	48	82	83	100
(2) Rondle and Morgan with sodium bicarbonate + sodium carbonate buffer (ref. 3)	75	96	93	100
(3) Boas (ref. 5)	34	98	69	100

of 8·8 and 9·8 respectively were used, whereas under these conditions values for glucosamine-6-phosphate showed the opposite trend (70 and 100 per cent respectively). Galactosamine gave significantly more colour when a buffer of *p*H 9·6 was used and thus showed an intermediate response.

The amount of coloured derivative formed from an amino-sugar in the Elson and Morgan reaction depends on both the *p*H and concentration of the alkaline salts present during the reaction with acetylacetone. Amino-sugars vary with respect to their stability in alkaline solutions, for example when muramic acid and glucosamine were incubated in 0·1 *N* sodium hydroxide for 1 hr. at 38° C. losses of hexosamine-reacting substance were 90 and 13 per cent respectively. The solution of alkali-treated muramic acid contained ammonia, and after acidifying the mixture with hydrochloric acid, a significant amount of substance was extracted with ether which gave a positive reaction for hydroxy fatty acid. After treatment with copper lime, the ether-extracted material gave a positive reaction for lactic acid[6]. About 10 per cent of the weight of original amino-sugar was recovered as lactic acid, and since significant amounts of this product were not obtained when either glucose or glucosamine was similarly treated it seems probable that the side chain on carbon atom 3 of the hexosamine moiety of 3-O-α-carboxyethyl-hexosamine[7] is released as lactic acid on treatment with alkali under relatively mild conditions. During this process the hexosamine moiety is destroyed.

From the results reported here it is clear that, particularly in the case of muramic acid, the conditions used for the determination of amino-sugars by the Elson and Morgan reaction should be rigidly controlled. Whenever possible, a pure sample of the amino-sugar being determined should be included as the standard, and the use of independently reported glucosamine values is not recommended.

I am grateful to Prof. W. T. J. Morgan for a sample of galactosamine hydrochloride and to Mr. A. G. Ness for some analyses.

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PHYSICAL INCOMPLETENESS OF INFLUENZA VIRUS PROPAGATED IN DE-EMBRYONATED EGGS

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'FAST' and 'slow' sedimentable components of the *PR8* strain of type *A* influenza virus may be selectively propagated in de-embryonated eggs[1,2]. Because the 'slow' form lacks several of the biological characteristics of the 'fast' form, it has been called 'incomplete' virus[1]. Hanig and Bernkopf[3] observed that the two forms exhibit 'fast' and 'slow' classes of sedimentation coefficients with overlapping distributions. These authors considered, nevertheless, that the 'fast' and 'slow' classes were distinctly different, and the overlapping was interpreted as resulting from differences in viscosity caused by differences in dilution of the various preparations. 'Incomplete' virus corresponding to slowly sedimenting overlapping components can also be propagated in embryonated eggs[3,4]. This effect has alternatively been ascribed to varying degrees of 'incompleteness' in a physical sense, a most attractive interpretation implying a parallelism in the development of the physical particle and its biological characteristics[5]. This may be the proper explanation for the overlapping observed in 'incomplete' virus propagated in embryonated eggs. Here, a gradual transition from 'complete' to 'incomplete' virus seemingly takes place during the several successive passages which appear to be necessary when using embryonated eggs for propagation[6–9]. In de-embryonated eggs, however, either component may be obtained directly in a single passage and alone, within the resolution of the optical system of the ultra-centrifuge.

Other differences between the two hosts are also apparent. The infectivity to agglutination ratios (I/A), after 24 hr., employed to characterize the viruses from the successive passages in embryonated eggs, seem to be appreciably lower than the ratios obtained from the 'incomplete' virus directly propagated in de-embryonated eggs. Thus, the mean infectivity to agglutination ratio reported[8–10] is 2·7 for virus from the third passage, the form which typifies the 'incomplete' virus from embryonated eggs. The mean, however, of the infectivity to agglutination ratios reported for the 'incomplete' virus propagated in de-embryonated eggs for the present investigation and elsewhere[1,2] is 5·0. Another, more obvious, difference is that virus grown in de-embryonated eggs is propagated only in the allantoic membrane while that from embryonated eggs may also be formed in other tissues, notably the yolk sac[8].

These differences suggested that, for influenza viruses, extrapolation of interpretations based upon observations in one host to another, even very

similar, host may not be a valid procedure without well-considered justification. It then follows that the interpretation of Hanig and Bernkopf[2] that the 'fast' and 'slow' forms of virus propagated in de-embryonated eggs are distinctly different physical entities may be correct. Should this be so, it is evident that if there is a physical transition from one form of the virus to another, it must take place in one discrete, large step rather than in many intermediate steps unless the intermediate forms are transient and unidentifiable. Accordingly, this communication is concerned with a more rigorous investigation than the earlier one[2] concerning the 'fast' and 'slow' forms of *PR*8 virus selectively propagated in de-embryonated eggs.

Variations from preparation to preparation in the sedimentation coefficients of influenza virus may be caused by the intrinsic viscosity of the virus solutions *per se*[11] determined at different concentrations. Concomitantly, variations may be caused also by the presence of extremely viscous contaminants such as the normal 30 *S* component[12,13]. It is to be expected, then, that the sedimentation coefficients determined at a number of decreasing concentrations for a single preparation and extrapolated to infinite dilution would eliminate both viscous effects and would yield values more representative of the 'fast' and 'slow' classes of virus.

'Fast' and 'slow' forms of the *PR*8 strain of type *A* influenza virus were propagated in 17-day de-embryonated eggs for 24 hr. by the method of Bernkopf[2] employing inocula diluted to 10^{-5} and 10^{-1}, respectively. Each of four preparations of eight dozen eggs yielded about 1,600 ml. of the 'fast' component. A similar four preparations of the 'slow' component were prepared. Purification and concentration were accomplished by (*a*) two, three or four alternate high- and low-speed centrifugations at 4° C., or (*b*) a combination of these preceded by adsorption and elution from chicken erythrocytes. One preparation of the 'fast' component was divided in half and each portion was purified by (*a*) and (*b*). The sedimentation coefficients at infinite dilution (S°_{20} ∞) were not significantly different for the two halves, 688 and 695 (Table 1, 6, 6*a*) indicating that the method of preparation probably had little effect on the sedimentation coefficient at infinite dilution. All operations were carried out in *p*H 7·4, *M*/15 phosphate buffer as follows: (*a*) infectivity was titrated in embryonated eggs[1] and calculated according to the Reed and Muench method[14]; (*b*) hæmagglutinating activity was measured by a modification of Salk's method[17].

Each preparation of virus of 6–8 mgm./ml. was diluted into five aliquots of decreasing concentrations in *p*H 7·4, *M*/15 phosphate buffer[15]. The uncorrected sedimentation coefficients, *S*, were determined at 20° C. in a Spinco model *E* analytical ultra-centrifuge employing a Philpot–Svensen optical system. Exposures were made at 4-min. intervals for 10 sec. at 12,590 r.p.m. Bar angles varied from 30°–45° depending upon the concentration of the sample in a 2°, 12 mm. cell. Both 'fast' and 'slow' components exhibited typical influenza virus boundaries in that there was considerable flattening of the schlieren peaks during a determination. No difficulty was encountered, however, in locating the maxima of the patterns. For each preparation *S* was plotted against *C* and extrapolated to infinite dilution by the method of least squares. In the range of concentrations employed, the curves were essentially linear whether plotted as $1/S$ versus *C*, or *S* versus *C*. The extrapolated values of *S* were corrected to the viscosity and density of water at 20° C. using $\rho_{20} = 1{\cdot}0081$ and $\eta_{20} = 1{\cdot}0467$ centipoise for the stock *p*H 7·4, *M*/15 phosphate buffer.

In calculating *S* for the 'fast' and 'slow' forms the apparent partial specific volume, $\overline{V}$, employed was 0·80 for both forms. This is the mean value of $\overline{V}$ reported by Lauffer and Stanley[13] for the 'fast' component propagated in embryonated eggs and the 'slow' form propagated by us in de-embryonated eggs. We were compelled to resort to this device because of insufficient 'fast' material from de-embryonated eggs on which to complete a determination. The value reported by Lauffer and Stanley was $\overline{V} = 0{\cdot}79$ and that determined by us employing identical procedures was $\overline{V} = 0{\cdot}806$. Because of the intrinsic experimental uncertainties in the determination of $\overline{V}$, we have considered these two values to be not significantly different from each other or from the 'fast' form in de-embryonated eggs, and have arbitrarily assigned $\overline{V} = 0{\cdot}80$ to both our 'fast' and 'slow' components. Calculations of the sedimentation coefficient at infinite dilution using the separate values of $\overline{V}$ in no way affects the interpretation of the results.

The results of the extrapolations of the sedimentation coefficients to infinite dilution (Table 1, Fig. 1) show that the two forms of virus fall into two discrete distributions. That produced from the 10^{-5} inoculum has a mean of 697 svedbergs, and that from the 10^{-1} inoculum a mean of 541 svedbergs with standard errors of the mean, $SE_{\bar{x}}$, of 4·3 and 4·1, respectively. This difference in sedimentation behaviour is quite unambiguous. Statistical analysis for the significance of the difference between means shows that $t = 14{\cdot}97$. Indeed, even when the extreme values of the two distributions that most closely approach one another, rather than the means, are chosen to calculate *t*, the result is still clear, $t = 12{\cdot}60$. Both these values of *t* are beyond the limits of conventional tables of probability and correspond to $P \ll 0{\cdot}001$ so that the

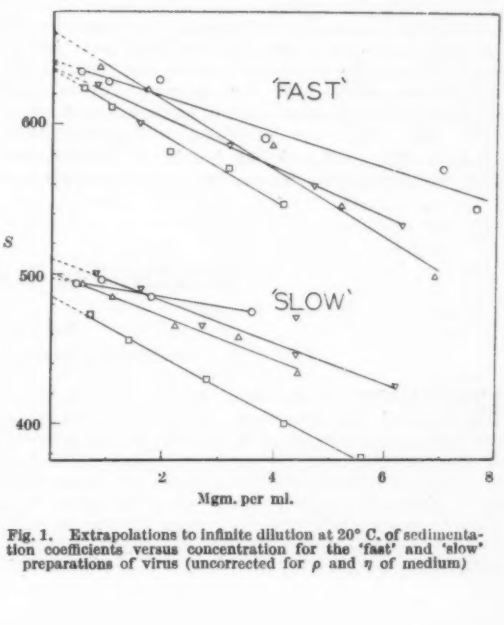

Fig. 1. Extrapolations to infinite dilution at 20° C. of sedimentation coefficients versus concentration for the 'fast' and 'slow' preparations of virus (uncorrected for ρ and η of medium)

Table 1. Sedimentation Coefficients Extrapolated to Infinite Dilution for 'Fast' and 'Slow' Components

Prep.	*HA**	ID_{50}	*I/A*	Purif.	$S^{w}_{20}\,\infty$
	10^{-1} inoculum				
1	—	—	—	Cent.	541
2	2·8	5·3	2·5	Cent.	526
3	2·8	6·2	3·4	*CRBC*	554
4	2·8	5·7	2·9	*CRBC*	543
	10^{-3} inoculum				
5	2·8	8·9	6·1	Cent.	718
6	2·6	9·1†	6·5	*CRBC*	695
6a	2·6	9·1†	6·5	Cent.	688
7	2·6	8·6†	6·0	*CRBC*	687

* Adjusted from 0·125 to 0·25 per cent *CRBC*. † Mean value of pool.

two distributions could be from the same population. In view of these results, the hypothesis[5,7,10] that overlapping continuous values of sedimentation coefficients for the two forms of virus are indicative of biological transitions of 'incompleteness' is untenable for virus propagated in de-embryonated eggs. The ranges of S reported earlier for the 'fast' and 'slow' forms of virus were correctly interpreted by Hanig and Bernkopf[2]. They arise simply from the dependence of S upon concentration in the ultracentrifuge cell.

It is still possible that virus with many intermediate sedimentation coefficients could be produced by inocula of dilutions intermediate between 10^{-1} and 10^{-3}. This experiment has not been performed in de-embryonated eggs. In embryonated eggs, inocula diluted to 10^{-3} result in two distinct components which sediment concurrently and which correspond to the 'fast' and 'slow' components of de-embryonated eggs[3,10]. In an extensive study, Gard *et al.*[10] have reported for 'incomplete' *PR8* virus obtained from embryonated eggs that the sedimentation coefficients ranged widely when extrapolated to infinite dilution. They do not, however, report details of their extrapolation procedures, so that a comparison of their results with ours, unfortunately, is not possible.

On the basis of the data available, it is valid only to state that for embryonated eggs there may or may not be continuous transitions from one form of the virus to the other and that the 'fast' form ranged from 757 to 810 svedbergs, while the 'slow' form ranged from 430 to 679. For the two forms of virus propagated in de-embryonated eggs, however, it is clear that they are completely disparate with $S^{w}_{20}\,\infty = 697 \pm 4{\cdot}3$ and $541 \pm 4{\cdot}1$. It is also clear that any hypothesis which attempts to explain a physical transition of one form of virus into the other when propagated in de-embryonated eggs must consider strongly the evidence that the transition probably would take place in a single, large, discrete step. At present, a conservative interpretation would be simply that, in the de-embryonated allantoic membrane, concurrent biological and physical developments proceed up to a certain point in the cell and then stop before release. The inoculum diluted 10^{-1} results in the physically 'slow' and biologically 'incomplete' form. The inoculum diluted 10^{-3} goes a discrete step further resulting in release of the physically 'fast' and biologically 'complete' virus. In embryonated eggs an inoculum diluted 10^{-3} results in the concurrent growth of both discretely different forms before release from the host cells.

Thus sedimentation coefficients extrapolated to infinite dilution have clearly demonstrated that there is no detectable gradual transition in $S^{w}_{20}\,\infty$ from one component to the other. Rather, the probability is much less than 1 in 1,000 that the two distributions, $541 \pm 4{\cdot}1$ and $697 \pm 4{\cdot}3$, could be from the same population. It follows from this that any hypothesis attempting to explain a physical transition of one form of virus to the other when propagated in the allantois must consider the evidence that the transition most probably would take place in a single, large, discrete step.

This investigation was supported by research grant *H*-2789 from the National Heart Institute of the National Institutes of Health, United States Public Health Service, and taken in part from a thesis submitted by one of us (J. M. S.) to the Graduate School of the University of Pittsburgh for the degree of master of science.

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BIOLOGICAL FUNCTION OF FRUIT

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RESEARCH work carried out by me has revealed the accepted conceptions concerning the biological function of fruit, that is, the influence of the fruit on seed germination, to be misleading. It should be kept in mind that many cultivated fruits have changed entirely from their original form. This is particularly true of fruits having a pulpy pericarp, which, through selection, hybridization and cultivation, has steadily increased in size, for example, apple, peach, pear, etc. Thus only an ecological approach, a study of the fruit in its natural form and habitat, can elucidate its biological functions.

The developmental cycle of fruit may be divided into four periods: (1) from fertilization until final development in size; (2) the period of chemical changes within the fruit, partly visible to the naked eye by changes in colour of the fruit; (3) the period of final fruit ripening during which a corky layer is

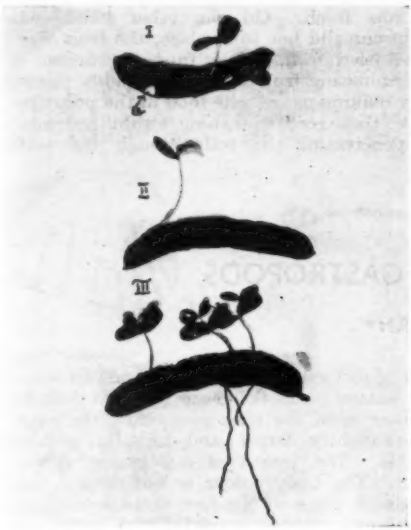


Fig. 1. Three developmental stages of the carob bean germ

formed between the pedicel of the fruit and the branch of the mother-tree ; (4) the period of chemical changes in the fruit when found on its natural litter.

While relatively sufficient information is available on the first three periods, data are scarce with regard to the fourth one. Research has been confined to the period when the fruit is best suited for consumption, or in determining storage conditions most suitable for preserving the fruit.

Fruits from indigenous indehiscent forest-trees and shrub species were collected soon after they had matured and stored at room temperature until sowing. One hundred fruits from each tree sample were sown in sandy seed-beds on the grounds of the Agricultural Research Station, Rehovot.

Fig. 2. A germ breaking through the split stony coat of a mango seed

Only healthy whole fruits were used, since my assumption is that the fruit represents a vital organism which, like the seed, continues to live after reaching maturity.

These experiments were supported by observations on the seeds of various fruit trees grown in Israel, for example, apple, anona, avocado, melon, tomato, pumpkin, grapefruits, lemons, *Artocarpus integrifolia* and others. These fruits were left in various storage conditions until maturity and carefully cut to see if their seeds had meanwhile germinated.

Table 1 shows percentage germination of various forest seeds when left within their fruits. Only the seeds of fruits not attacked by fungi or insects germinated. The low percentage obtained is not representative for the various species as the fruits were sown in poor sand ; on natural litter percentage of germination would obviously have been greater.

Table 1. Germination of Seeds within their Fruits

Species	Germination (per cent)	Length (days)
Arbutus andrachne	32	62
Celtis australis	78	102
Ceratonia siliqua	9	76
Elaeagnus angustifolia	14	49
Laurus nobilis	19	106
Melia azederach	64	61
Pyrus syriaca	40	102
Rhamnus alaternus	44	61

Fig. 1 shows the developmental stages of the carob bean germ. Fig. 2 shows a germ breaking through the split stony coat of a large mango seed.

When testing fruits of *Arbutus andrachne*, *Ceratonia siliqua* and *Mangifera indica*, the seeds of which germinated in the sown beds, we found that, before sowing, their *p*H was 4·12, 4·85 and 4·2, respectively. After germination within the fruits their *p*H increased to 5·38, 6·34 and 5·5, respectively. Even the germination of the seed of the avocado in its fruit is no rare occurrence. In this fruit there is a *p*H change after harvesting from 6·8 to 7·05 at the time of germination of the seed.

Germination of seeds within the fruit itself was observed in tomato, apple, *Cucurbita maxima*, avocado, anona, grapefruit and lemon. Within the last two fruits green cotyledons developed from the germinating seeds when the fleshy pericarp was still entirely closed. The roots of the germs were in all cases tightly attached and had partly penetrated into the body of the fruit.

From our experiments and observations it seems therefore clear that the so-called inhibiting substances which prevent the seed from germinating change, in the course of the metabolism of the fruit, into new compounds which favour seed germination. The biochemical composition of the fruit reaches a stage whereby the radicle of the germ is enabled to come in touch with the pulpy content of the fruit and thus provide it with its first food before it reaches the mineral soil in the forest litter.

It appears, therefore, that the fruit is naturally a disseminating organ the structure of which is adjusted to the ecological conditions of its habitat. The better results obtained by extracting the seeds artificially should not diminish the positive function of the fruit in Nature as a disseminating organ.

The supposition that flavour and taste of fruit attract the senses of animal and man to eat and disseminate the fruit is therefore not necessarily justified, and it is only a happy accident in Nature that man

or animal consumes the fruit at a stage suitable to his taste. The conclusion drawn by different workers that the fruit in Nature is an inhibitor to the germination of its seeds or should be destroyed by insects or fungi and freed for germination also does not seem warranted.

Examining the sown fruits from time to time showed that seed germination occurred wherever the fruit was fresh. On the other hand, wherever germination did not take place, the fruit was found to have been destroyed by fungi or insects. Within the germinating fruit the roots steadily increased in size by making use of the food in the pulpy pericarp, many of these roots branching within the fruits rather than penetrating the soil through the perforated coat.

AUSTRALIAN BIVALVE GASTROPODS

By ROBERT BURN*

As already intimated by me (*Nature*, April 9, p. 179), *Edenttellina typica* Gatliff and Gabriel[1] has been collected alive at Torquay, Victoria, and it is congeneric with the Japanese *Tamanovalva limax* Kawaguti and Baba[2]. Thus the latter genus is a synonym of the former. Furthermore, I suggest that the Victorian and Japanese species are conspecific with *Edenttellina corallensis* Hedley[3] from Queensland and *Scintilla ? chloris* Dall[4] from California, but not with *Edenttellina typica* as described and figured from South Australia by Verco[5] and Hedley[3]. My reasons for suggesting this synonymy are given in the discussion following the description of the Victorian species.

Overseas correspondents inform me that the Eocene Paris Basin fossil genus *Berthelinia* Crosse[6] is applicable to the present species, and with this I wholly agree. This means that the two synonymous recent genera must themselves become synonyms of this earlier name. It is then under this genus that I thus describe the animal and shell of the Victorian species: *Berthelinia typica* (Gatliff and Gabriel).

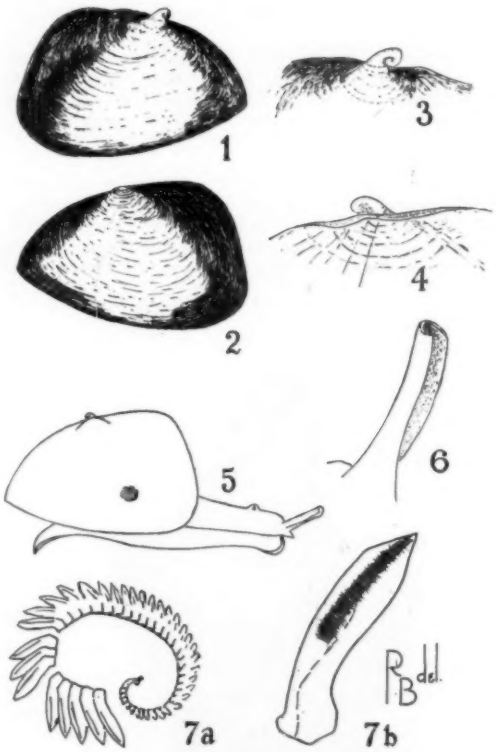
Notice of a second species from the same habitat was also given in my communication in *Nature* of April 9. This species presents a new problem within the order Sacoglossa, for the protoconch, although always present on the umbo of the left valve, shows lateral torsion away from the vertical plane of the initial whorl. Together with other shell characteristics and the very different animal, the species deserves generic separation, and to this end I propose the name *Midorigai australis gen. et sp. nov.* for it. *Midorigai* is chosen to perpetuate the Japanese ordinal name for the sacoglossan opisthobranchs.

A specimen of each species has been presented to the Japanese authors in exchange for topotypes of their own find. The remainder of the material, including the exchanges, has been presented to the National Museum of Victoria, Melbourne.

I wish to thank Mr. C. J. Gabriel of Melbourne for allowing me to examine cotypes and topotypes of both *Edenttellina typica* and *E. corallensis* from his collection. To Tom Iredale of Sydney go my special thanks for directing my attention to this matter in the first place and for urging me to try to resolve the *Edenttellina–Tamanovalva* problem.

Berthelinia typica (Gatliff and Gabriel)

The animal (Figs. 1–7) does not differ essentially from that described for *Tamanovalva limax* Kawaguti and Baba (ref. 2, 179–180, Fig. 1, 4–5). The few points of difference are: (1) the smaller size of the whole animal; (2) the more elevated rounded protuberance upon the neck containing the eyes; and (3) the slightly larger and broadly pointed oral tentacles. The length of my largest specimen is 6 mm. The body colour is leaf-green; the neck, transparent edges of the foot and the mantle inside the shell are minutely speckled with cream pigment. The rhinophores have larger denser patches of creamy yellow towards the tips, while the lateral slit is similarly pigmented. The mantle in each valve



Berthelinia typica (Gatliff and Gabriel).

(1) Left valve of shell. (2) Right valve of shell. (3) Detail of protoconch on umbo of left valve. (4) Detail of hinge line of left valve. (5) Living animal from right side. (6) Dorsal aspect of right rhinophore. (7) Radula: *a*, complete series; *b*, detail of a large tooth

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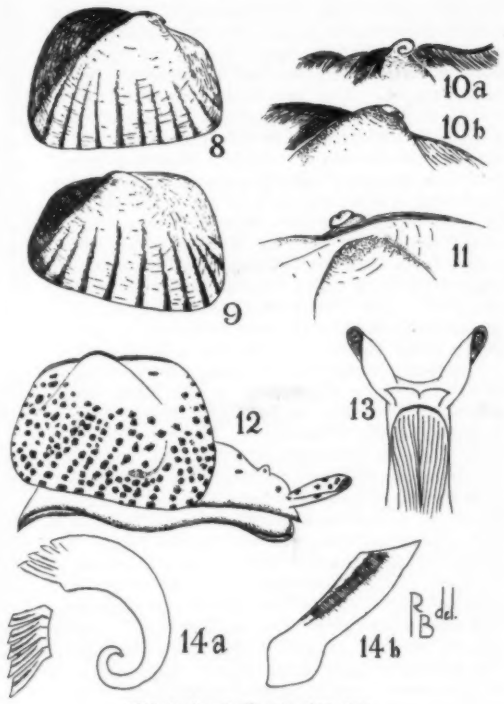

Midorigai australis gen. et sp. nov.

(8) Left valve of shell. (9) Right valve of shell. (10) Detail of protoconch: *a*, dorsal aspect; *b*, lateral aspect. (11) Detail of hinge line of left valve. (12) Living animal from right side. (13) Underside of head and anterior foot. (14) Radula: *a*, complete series; *b*, detail of a large tooth

contains red pigment cells in patches of varying area; in some specimens the whole mantle is thus red pigmented. The adductor muscle shows as a grey-blue circular patch on each valve.

The radula contains 41 or more teeth similar to those of *T. limax* (*loc. cit.*, Fig. 8). The spiral series of teeth is broken into three sections, 6 large teeth in the lower series, 3 similarly sized teeth in the ascending series, and 32 or more evanescent teeth in the descending series.

The shell is as figured by each of the authors cited and I add figures of the present specimens (Figs. 1–4). The protoconch is elevated, erect, of 1½ whorls in the vertical plane. The valves are smooth with fine growth lines visible. The adductor muscle is firmly attached to the left valve and easily detached from the right, the scar is circular, nacreous inside the valves and visible externally. There are no teeth in the hinge line. There is a strong leathery transparent periostracum over each valve, the thickening and strengthening of which provides the ligament upon which the valves hinge at the umbones. The largest shell measures 5 mm. long, 2·5 mm. high and over the paired valves 1·5 mm. The shell is pale translucent olive-green, the protoconch white, the ligament brown and the periostracum colourless or pale horn colour.

Material examined: 1 specimen, Torquay, February 2, 1960; 3 specimens, Torquay, March 5, 1960.

The species lives on the green alga *Caulerpa scalpelliformis* (R. Brn.) C. Ag. which grows either in isolated colonies of a few leaves in the narrow crevices between rocks or as single stipes some little distance apart among the denser brown algae on the top of rocks, in the channels at the outer edge of the reef where there is strong tidal influence. The small specimens live upon the pale green stalks and roots of the alga; consequently these specimens are paler in colour. The adult specimens feed on the sharp flat sword-like edges of the alga; a minute hole is pierced by the radula and the surface juices are sucked out, leaving a narrow band easily discernible by its yellowish colouring. The animal when irritated exudes great quantities of white viscous fluid from the hyperbranchial ducts opening on the posterio-ventral margins of the mantle. At rest, the species retracts the head within the shell, which takes up a vertical position on the alga, as though attached by a strong byssus; in this attitude it resembles most closely a small green species of Pelecypoda.

Crosse[6], originally described *Berthelinia* from a single juvenile valve; later, together with Fischer[7], he described the complete shell, clearly indicating the position, shape and size of the adductor muscle scar, and most important, the erect protoconch in the vertical plane of the valve. There can be no doubt that this genus is applicable to the present species. The comparison of the Victorian and Japanese species clearly indicates that they are congeneric and, except for a few minor points, conspecific. I have dissected out and examined the radula of each species, and I find that both contain a similar number of teeth, 41 or more, which is more than indicated by Kawaguti and Baba. That the teeth are in three series in both radulæ is possibly due to the contraction of the body during preservation, but as *Midorigai australis* preserved in the same manner exhibited only two series, I feel that the three series may be a generic characteristic.

Although the Japanese authors do not mention it, I find that there is a thin transparent periostracum present on each of the valves of *Tamanovalva limax*, and that it is thickened in the same way as in my specimens, thus providing the 'invisible' ligament. It is quite possible that Verco's South Australian specimens are not this species, but instead are some new species with teeth in the hinge line and a large vertical protoconch of about two whorls; the shell is also more attenuated posteriorly, and the adductor muscle scar and the animal are unknown. The South Australian specimens described first by Verco and later by Hedley cannot be traced at the present time.

My specimens and the Japanese topotypes resemble most closely *Edenttellina corallensis* Hedley; the topotypes of this species in Mr. Gabriel's collection cannot be separated in any real way from *Berthelinia typica* cotypes in the same collection. Thus I must reduce *E. corallensis* and also *T. limax* to synonyms of *B. typica*. The Californian *Scintilla? chloris* Dall is larger, length 9 mm., but is still remarkably similar to the present species, and I think should be added to the synonymy of it.

Midorigai gen. nov.

This new genus is proposed for those sacoglossan slugs similar to *Berthelinia*, but with the following differences. The shell is more obese, the shape more square, the protoconch very much smaller and in a nearly horizontal plane across the hinge line of

the two valves. There are two adductor muscles; the lower, larger one is horizontally oval, with an anterior flange rising up towards the upper, much smaller, muscle just below the anterior hinge line. The foot is narrower than the neck. The rhinophores are stout and at mid-length swollen; the oral tentacles are large and pointed. The vaginal pore is in front of the lower adductor muscle. Radula is as usual in the Sacoglossa, teeth more coarsely denticulate laterally than in *Berthelinia*. Body-colour is dark green, the mantle within the shell is spotted with large cream spots, the neck and rhinophores with a few paler cream patches.

Midorigai australis sp. nov.

In the type species (Figs. 8–14) the body is stout and the foot is nearly as wide as the neck. The neck is high and rises up towards the shell from immediately behind the eye prominence. The eye prominence is broadly elevated and close to the rhinophore bases. The auriculate rhinophores are stout, swollen at mid-length with the bases constricted; the tips are rounded and not square as in the previous species. The oral tentacles are large, square-lobate with the anterio-lateral corners sharply pointed. The anterior edge of the foot is bilabiate, the upper lip medianly slit, the lower continuous and rounded in shape. The sole is medianly grooved for its whole length; on each side of this groove there are six faint grooves originating near the anterior end of the foot, and these carry the mucus or pedal fluids from the glands within the bilabiation of the anterior part of the foot. The foot is flattened anteriorly and folded along the median groove posteriorly. The penial aperture is behind the right rhinophore base, but in front of the level of the eyes; the vaginal pore is small and in front of the lower adductor muscle. The tail of the foot is very little shorter than the posterior of the shell. The length of the largest animal was 5·5 mm. The anus opens above the posterior ridge of the foot within the shell. The ducts from the hyperbranchial glands open in the margins of the mantle behind the anus. The gill is bluish, larger than in *B. typica*, and situated between the anus and the adductor muscles. The lower larger adductor muscle is placed in the anterior part of the shell, but rather far back from the anterior margin; it is horizontally oval with an anterior flange of muscle running forward and curving upwards to the much smaller elongate-oval adductor muscle near the hinge line. This latter muscle can be observed by careful scrutiny of the living animal.

The radula has as usual two series of teeth in its uniseriate spiral. There are 5 teeth in the ascending series, and about 34 in the descending series; the whole spiral is more tightly coiled than in *B. typica*. The teeth are coarsely denticulate laterally, the tips being sharply angled towards the cutting edge.

The body colour is dark green, the rhinophores have large yellowish patches spread sparsely over them, and patches of the same size extend over the body. The mantle within the valves is densely spotted with large rounded spots of yellow-cream; some of these form wavy series which originate in the squarish yellow patches unequally spread along the mantle edges. The sole is pale green, the anterior edge of the foot whitish. The eye prominence is white, the eyes black.

The shell of the largest specimen measures 4·4 mm. long, 3 mm. umboventrally and 1·75 mm. broad. The left valve is the more convex of the two and is a little higher at the hinge line than the right, which fits under this higher upper edge; the ligament thus takes a vertical position, not a horizontal position as in *B. typica*. The protoconch is small and flatly coiled in its horizontal position on top of the umbo of the left valve; it encroaches upon the right valve for half its diameter. There is a strong translucent periostracum over the thin valves, which is strengthened and is coloured dark brown where it forms the ligament. The ligament extends twice as far in front of the umbo as behind it. There are no teeth in the hinge line. The valves are pale translucent olive-green with darker rays of green radiating out from the umboes. The protoconch is yellowish and thus inconspicuous. The interior of the valves is nacreous, particularly the lower adductor muscle scar.

Material examined: 1 specimen (holotype) Torquay, February 21, 1960; 5 specimens (paratypes) Flinders, Victoria, March 20, 1960; 1 specimen Torquay, April 2, 1960.

At Torquay this species lives upon the green alga *Caulerpa scalpelliformis* along with *Berthelinia typica* and the oxynoid sacoglossan *Oxynoe viridis* (Pease). At Flinders it lives upon the tender tips and needle-like leaves of the 'rat-tail' green algae *Caulerpa brownii* (C. Ag.) Endl. and *C. simpliciuscula* (Turn.) C. Ag. Both these algae grow outwards from the vertical walls of deep rock pools and channels at the extreme edge of the reef at Flinders. The animal exudes copious quantities of white viscous fluid from the posterior gape of the shell. The ventral margin of the closed valves gapes a little to allow the foot to protrude. In motion, the foot is thrust forward and the shell drawn towards the head in two or three jerky movements. The right valve contains none of the viscera.

This species can be separated from *Berthelinia* by the following criteria: (1) the small protoconch placed half on the right valve; (2) the right valve smaller than the left; (3) the foot narrower than the neck; (4) the swollen rhinophores; (5) the two adductor muscles; (6) the two series of teeth in the radula; and (7) the darker colouring and the spotting within the shell. Perhaps the shell both Verco and Hedley called *Edenttellina typica* is more closely related to this species than to *Berthelinia*.

That a second genus and species should occur along with one known for fifty years is truly remarkable, but no more so than the plentiful occurrence of *Berthelinia typica* (= *Tamanovalva limax*) in Japanese waters. Wider researches in similar habitats will probably reveal more forms of the same types as those described here.

Note added in proof. Dr. K. Baba, of Osaka (*in litt.*, received May 25, 1960) considers *B. typica* to differ specifically from *B. limax* because of its different shell shape and somewhat differently formed apices of the radular teeth. I regard these two species as the known extremes of zoogeographical variation within a single species, with *B. corallensis* and *B. chloris* as intermediate intergrading forms. Further material of all forms will perhaps allay the present differences of opinion.

[1] *Proc. Roy. Soc. Vict.*, N.S., **24**, 190, pl. 46, Figs. 5–6 (1911).
[2] *Biol. J. Okayama Univ.*, **5**, 177–184 (1959).
[3] *Proc. Malac. Soc. Lond.*, **14**, 74–76 (1920).
[4] *Proc. Biol. Soc. Washington*, **31**, 5–8 (1918).
[5] *Trans. Roy. Soc. S. Aust.*, **40**, 596–597 (1916).
[6] *J. Conchyliol.*, **23**, 79–81, pl. 2, Fig. 3 (1875).
[7] *J. Conchyliol.*, **35**, 305–311, pl. 10 (1887).

LETTERS TO THE EDITORS

ASTRONOMY

Origin of the Solar System

THERE is a considerable degree of order in the solar system which current theories seem capable of explaining only in part. The present communication describes a new approach which has led to a proposed model for its formation which seems to be much more successful in explaining the regularities observed.

This model, in common with some others which have been advanced, envisages the passage of a star into the neighbourhood of the Sun. The order of magnitudes under consideration at present envisages a star of one hundred Sun masses moving with a velocity of 100 km./sec. and approaching the Sun to within a distance of ten times the solar radius. The Sun is imagined as initially spinning about an axis not in the plane of the orbit of the star. A tide is raised on the surface of the Sun which increases in height as the star approaches. Eventually a position is reached where a portion at the tip of the tidal bulge facing the Sun is under a greater gravitational pull from the star than from the Sun itself, and this portion then breaks away and, moving under the combined gravitational attractions of the star and the Sun, forms the planet Pluto.

This loss of material at the solar surface sets up waves which will travel around the Sun from the unaffected obverse tidal bulge towards that part of the Sun facing the oncoming star. The wave-crest approaches the oncoming star which eventually draws off another portion of the solar material to form the planet Neptune. A new wave is initiated to give the planet Uranus, and then Saturn and Jupiter are formed in a similar way. At this stage the star is approaching most closely and is able to draw material out from the Sun almost continuously, a great deal of which material it may even capture. Indeed a large planet could have been formed at this stage and captured by the star. The residue of the ejected material forms the belt of asteroids, which lie for the most part between the orbits of Jupiter and Mars. Finally, as the star recedes, the four smaller planets—Mars, Earth, Venus and Mercury—are formed.

Fig. 1 shows the possible scheme of operation. It is hoped that the regular time-intervals between the production of each planet will account for the well-known but hitherto unexplained Bode's law. In support of this idea it may be noted that the same law, with different constants, also applies to the innermost satellites of those planets possessing appreciable satellite systems (Table 1). The proposed

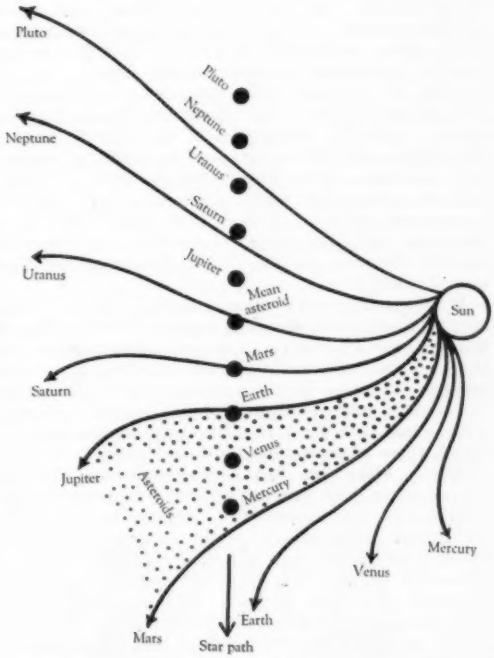

Fig. 1. Suggested scheme for the origin of the solar system. The position of the passing star when each planet leaves the Sun is indicated by ●

mechanism for their formation is similar to that given above, but with the planet itself acting as the parent body. However, the agreement with Bode's law is not so precise because of the perturbing influence of the Sun.

An interesting point concerns the time taken by the whole process. If the waves on the surface of the Sun are considered as gravity waves on a deep liquid of wave-length equal to the circumference of the Sun, travelling a distance equal to one half the circumference, it is found that the time for the journey of each wave is about 80 min. Thus the material for the formation of the planets will have been removed from the Sun in a total time of 12 hr. Of course, many hundreds of years will have elapsed after the passage of the star before Pluto, the outermost planet, had completed its first orbit.

Full consideration of the model gives reasonable qualitative explanations for the following observed

Table 1

Jupiter			Saturn			Uranus		
Satellite	Bode-type law	Orbit radius ($\times 10^4$ km.)	Satellite	Bode-type law	Orbit radius ($\times 10^4$ km.)	Satellite	Bode-type law	Orbit radius ($\times 10^4$ km.)
1	19+ 0= 19	18·1	1 (Mimas)	18·6+ 0 =18·6	18·6	1 (Miranda)	14+ 0=14	13·0
2 (Io)	19+ 22= 41	42·2	2 (Enceladus)	18·6+ 4·8=23·4	23·8	2 (Ariel)	14+ 6=20	19·2
3 (Europa)	19+ 44= 63	67·1	3 (Tethys)	18·6+ 9·6=28·2	29·5	3 (Umbriel)	14+12=26	26·7
4 (Ganymede)	19+ 88=107	107·1	4 (Dione)	18·6+19·2=37·8	37·8	4 (Titania)	14+24=38	43·9
5 (Callisto)	19+176=195	188·4	5 (Rhea)	18·6+38·4=57·0	52·7	5 (Oberon)	14+48=62	58·7

phenomena and physical properties of the solar system: (i) The occurrence of a law (it is hoped Bode's law) for the radii of the planetary and satellite orbits. This is a result of the regular time-sequence of their production. The departure from the law for the outermost planets is also explained. (ii) The relative masses of the planets (including Mars) and of the satellites in each system. (iii) The large eccentricities of the orbits of Mercury and Pluto. (iv) The inclinations of the planetary orbits to the ecliptic. (v) The periods of rotations of the planets about their axes. (vi) The inclination of the planetary equators to their orbits. (vii) The inclination of the solar equator to the ecliptic and the variation of its period of rotation with latitude. (viii) The retrograde spin of Uranus and the retrograde orbits of its satellites. (ix) The retrograde orbit of Triton, the inner satellite of Neptune, and the large eccentricity of its other satellite, Nereid. (x) The origin of the satellites Titan and the Moon.

It is hoped to carry out calculations on the University of Manchester Mercury computer to see whether the basic ideas behind such a system are feasible, and, if so, to find values of the constants that would give an approximation to the system as it exists at present.

I wish to acknowledge the many helpful discussions I have had with Prof. H. Lipson during the period in which these ideas were being formulated.

Note. After this short communication had been prepared, it was found that a communication on a similar topic had appeared in *Nature* of May 21, p. 621, by Egyed. The theory presented here would seem to have the advantage that it explains the origin of the solar system in terms of readily understood physical principles without invoking rather exotic phenomena, such as the variation of G with time. Other observations, for example, the distribution of angular momentum in the solar system, also seem more readily explained by the mechanism proposed here.

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PHYSICS

Photo-Injection of Charge into Dielectric Liquids

Although many workers have studied the electrical breakdown of pure highly insulating liquids, few have been concerned with the fundamental processes of charge production and movement. This is because of the experimental limitation set by the extremely low natural conductivity. By applying high electric fields or high-energy radiation the conductivity of very pure dielectric liquids may be enhanced; but in both cases it remains difficult to devise experiments to study the mechanism. The difficulties may be partly overcome by a new method of increasing the conductivity. This is by ultra-violet illumination of the electrodes: some preliminary experiments on this effect are reported in this communication.

Dornte[1] was apparently the only early worker to observe a dependence of the current in pure dielectric liquids on ultra-violet radiation. More recently, Le Blanc[2] used the effect to measure the charge mobility in liquid *n*-hexane, but neither of them investigated

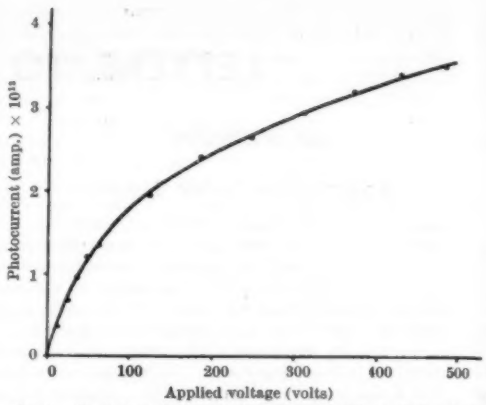

Fig. 1. Typical variation of photocurrent with applied voltage (1-cm. diam. electrodes spaced 7 mm. apart)

it further. It has probably been overlooked by other workers because of their use of glass test cells or of air-saturated liquids. It has recently been found that the ultra-violet photocurrents can be induced in a dielectric liquid only if it is thoroughly degassed, and for the work described here this was achieved by final distillation at a pressure of less than 10^{-5} mm. mercury. Similarly, dissolved oxygen has been shown to be a critical impurity in the electrical breakdown of pure liquids[3].

The liquid used in the present work was highly purified *n*-hexane having a residual conductivity of 10^{-16}–10^{-17} mho/cm. With low applied fields the current can be increased by a factor of at least 10^3 by focusing the ultra-violet radiation from a medium-power mercury discharge lamp on to the cathode. The photocurrent varies markedly with voltage as shown by the typical result of Fig. 1. The cell used for this work was completely sealed off at a pressure of 10^{-6} mm. after filling with the degassed liquid. By freezing out the hexane in a side bulb with liquid nitrogen the photoelectric emission from the same cathode could be studied in a good vacuum. As expected, the photocurrent in vacuum shows good saturation with voltage, and with a field of 170 V./cm. the currents are between 200 and 2,000 times greater than in the liquid for the same illumination.

By using optical filters it has been possible to obtain a rough measure of the spectral response for the photocurrent in both cases. For an aluminium cathode in vacuum the photoelectric threshold corresponded to a work function of about 4·1 eV. Approximately the same long-wave threshold was obtained for the photocurrent induced in hexane with a low applied field. There is no doubt that photocurrents are produced in the liquid by radiation of wave-lengths up to 3000 Å., that is, far beyond the absorption limit (~2000 Å.) for the liquid itself. This indicates that the current originates at the cathode, but the lack of saturation, and other features to be described, show that the process is very different from photoelectric emission into a vacuum. For this reason the release of charge from the cathode into the liquid is better described by the term 'photo-injection'.

Further investigation of the spectral response of the liquid photocurrent has indicated that the threshold wave-length increases slightly as the applied voltage is increased, although the effect contributes

only very little to the lack of saturation shown in Fig. 1. It has also been found that the form of the dependence upon voltage varies with wave-length. For example, the curve of Fig. 1 was obtained using the unfiltered radiation from a mercury lamp, but a more nearly ohmic characteristic is obtained by isolating wave-lengths near the threshold.

The transient response of the photocurrent on suddenly illuminating the cathode has also been studied, and this can be related to the charge mobility as measured by Le Blanc[3]. With the equipment used so far it has only been possible to record transit times of the order of seconds for the movement of the injected charge between the electrodes. This has indicated a mobility of about 5×10^{-4} cm.^{2}/volt sec. at room temperature, that is, slightly lower than found by Le Blanc. However, it is disturbing to find that with very low applied fields the transit time appears to depend on the wave-length of the ultra-violet illumination. The transients are further complicated by slow variations with time.

From these measurements there appears to be no doubt that photo-injection of charge into a dielectric liquid is possible. The dependence upon voltage shows, however, that it is not justified to assume, as is commonly done[4], that electron emission into a liquid is similar to that into vacuum. The injection of charge through a space charge barrier at the interface of the liquid and the metal seems much more likely[5], but many experiments are required before it is possible to work out the details. The ability to inject charge into a dielectric liquid opens up several interesting possibilities for investigating charge movement. Further work is being carried out and will be reported in more detail elsewhere.

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An Ionization Detector for Permanent Gases

Three highly sensitive gas ionization methods for the detection of volatile substances have been reported: the hydrogen flame ionization detector[1], the 'argon' detector[2], and the electron affinity ionization detector[3]. These devices are practical and efficient in the measurement of low concentrations of organic vapours; they suffer, however, the disadvantage of a slight or negligible response to most permanent gases. This communication describes a sensitive ionization method of measuring the concentration of all permanent gases, except the noble gases, in an argon carrier-gas stream.

The physical basis of the method is as follows. When argon containing free electrons is exposed to an electrical field, the temperature of the free electrons is rapidly raised to a level far above that of the argon atoms. This is because only a small proportion of the energy gained by the electrons from the field is lost during their elastic collisions with the argon atoms[4]. Collisions between free electrons and the molecules of other gases, except the noble gases, are by contrast non-elastic and result in the loss of a large proportion of the energy of the colliding electron. The addition of a small quantity of some other gas to argon causes, therefore, a reduction of the free-electron temperature at a given field intensity. There are several possible methods for observing variations of the free-electron temperature in argon when it is contaminated with other gases. The quenching of the normal response of an 'argon' detector has been suggested[5]; a more direct method is described here.

An ionization chamber of plane-parallel geometry is filled with argon and contains a source of free electrons. The chamber is connected directly across the input of a d.c. amplifier, and the anode of the chamber fed through a condenser with positive pulses of short duration (between 1 and 10 μsec.). When the chamber contains only pure argon, little or no current is observed to flow; this is because during the short period of the pulse there is insufficient time to permit the deflexion and collection of the fast-moving free electrons. With contaminated argon, however, the electron temperature is lower and they are moving slowly enough to permit their collection during the application of the pulse. The chamber therefore provides a signal current related to the concentration of the contaminant gas.

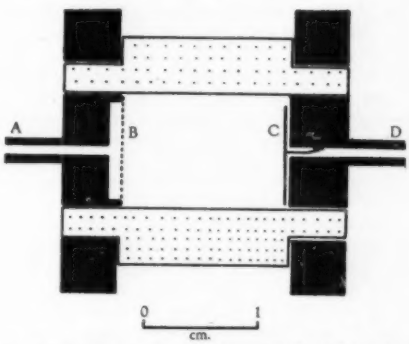

Fig. 1. Construction of the detector. (*A*) Gas inlet and anode connexion; (*B*) gas-flow diffuser made from 100-mesh wire gauze; (*C*) radioactive source; (*D*) gas outlet and cathode connexion. Black, brass; stippled, polytetrafluoroethylene

Fig. 1 shows the construction of a practical detector; its dimensions and the materials of its construction are indicated with the figure. The most convenient shape of electrical pulse to apply to the chamber is a half-wave rectified sine-wave. With a detector of the type illustrated, the frequency of the sine-waves used to generate the pulses should be between 0·2 and 0·7 Mc./s. and the amplitude of the pulses between 50 and 100 volts. Electrons are set free from the argon within the chamber by irradiation with soft β-particles from a sheet of metal foil containing tritium as the active element. The quantity of tritium should be sufficient to provide a d.c. saturation current of between 3 and 10×10^{-9} amp.

Fig. 2 shows the variation of current-flow in the detector with the frequency of the applied pulses. In pure argon no current flows when the frequency is higher than 0·27 Mc./s. When other gases are present at a concentration of 0·1 per cent by volume, there is an extension of the range of frequency over

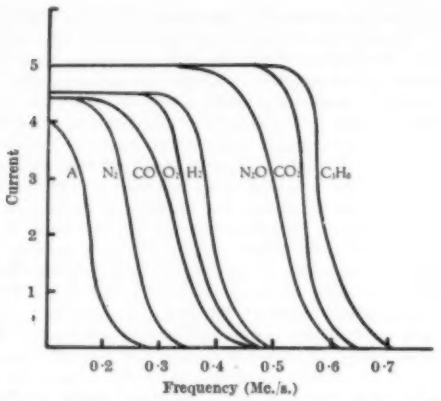

Fig. 2. Response of the detector to pure argon and to 0·1 per cent by volume concentration of various other gases in argon. Abscissa, frequency in Mc./s. of the applied half-wave rectified sine-waves. Ordinate, current drawn from the detector $\times 10^9$ amp.

which a current flows in the chamber. In general, the more complex the molecule of the contaminant gas the higher the frequency at which a current can still be observed. In practice it is possible to distinguish between such gases as nitrogen, oxygen, carbon dioxide and organic vapours simply by adjusting the frequency of the pulses applied to the detector.

When operated at a frequency of 0·27 Mc./s., the detector illustrated is capable of responding to all but the noble gases. The background current in pure argon is less than 10^{-10} amp. and the noise-level at a total time constant of 1 sec. less than 10^{-13} amp. The least detectable concentration of diatomic and of polyatomic gases in argon is approximately one in 10^7 and one in 10^8 by volume respectively. Helium or nitrogen can replace argon as the carrier gas, but the sensitivity is then greatly reduced.

The response of the detector is linear with gas concentration up to 1 per cent by volume of the diatomic gases. Using the detector illustrated in Fig. 1 the response to polyatomic gases is somewhat non-linear, especially at high frequencies. Recent experiments have shown, however, that the response to the concentration of polyatomic gases is dependent on the dimensions of the chamber and the magnitude of the primary electron current. There is reason for believing that with a modified design a linear response to the concentration of all gases can be achieved.

The device described would appear to have promise as a transducer for the concentration of permanent gases and of vapours such as water vapour which are otherwise difficult to measure.

I am indebted to Dr. S. R. Lipsky, of Yale University, for his advice and suggestions, and to Mr. P. Simmonds for expert technical assistance.

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Yield Stress exerted on a Body immersed in a Bingham Fluid

It is well known that finely divided, flocculated, aqueous suspensions of clay behave as Bingham fluids at concentrations less than about 25 per cent by volume. That is, their equation of flow is:

$$S = S_0 + \eta_l D$$

where S = shear stress applied, S_0 = minimum shear stress which will cause shearing, D = rate of deformation of the suspension, η_l = plastic viscosity.

Because such suspensions can resist stresses below a maximum value (often called the yield stress) without shearing, they should be able to hold bodies, in a certain range of density and size, stationary within themselves. A body should move only when the difference between its density and that of the suspension is sufficient for it to develop a force greater than that exerted on it through the yield stress of the suspension. The problem is to determine the magnitude of this limiting force, which we will call F_s.

For a cube falling with its faces horizontal and vertical, Yancey, Geer and Sokaski[1] have assumed that the minimum value of F_s would result from the yield stress S_0 acting over the bottom face only of the cube. Meerman[2] suggested that S_0 would act at least over the total vertical area of the cube, and Whitmore[3] that it would act over the whole surface area of the cube. We have so far been unable to find any reference to experimental measurements having been made on bodies, and, in order to test the various ideas, we have made some ourselves.

In our method the body is hung in the suspension by a fine thread attached to the free end of a horizontal wire, the other end being clamped to a bracket which can be raised or lowered on a screw thread. The body is of such a density as to sink in the suspension. When the body is in position in the suspension the free end of the wire is raised slightly then very carefully allowed to fall until the body comes into equilibrium, with F_s acting upwards on it. The bracket is then lowered about $1\frac{1}{2}$ in., and carefully raised to its previous position. F_s is now acting downwards on the body, and the free end of the wire is a distance D_s below its original position. Thus $F_s = c\frac{D_s}{2}$, where c is the proportionality constant of the wire.

If S_0 acts uniformly over a body, the magnitude of F_s should be independent of the orientation of the body. However, measurements on two glass blocks, sized $6{\cdot}2 \times 1{\cdot}9 \times 0{\cdot}8$ cm. and $4{\cdot}1 \times 1{\cdot}9 \times 0{\cdot}8$ cm. in a 20 per cent by weight suspension of 'Supreme' kaolinite clay supplied by English Clays Lovering Pochin and Co., Ltd., showed that the orientation had a big effect on the value of F_s (Table 1). The reproducibility of F_s was in all cases better than ± 8 per cent.

Table 1

Block	Horizontal face (cm.²)	F_s (dyne)
A	$6{\cdot}2 \times 1{\cdot}9$	3,610
	$6{\cdot}2 \times 0{\cdot}8$	2,230
	$1{\cdot}9 \times 0{\cdot}8$	1,390
B	$4{\cdot}1 \times 1{\cdot}9$	2,690
	$4{\cdot}1 \times 0{\cdot}8$	1,420
	$1{\cdot}9 \times 0{\cdot}8$	1,130

If it is assumed that different yield stresses prevail on the horizontal and vertical surfaces it can easily be shown that the best values to suit both of the bodies are :

Horizontal-face yield stress 145 ± 15 dyne cm.$^{-2}$

Vertical-face yield stress 29 ± 3 dyne cm.$^{-2}$.

The yield stress as obtained from viscosity measurements made with a Ferranti rotating-cylinder viscometer at 5 rates of shear was 52 dyne cm.$^{-2}$.

Thus it is clear that for suspensions of this type yield stresses obtained from viscometer measurements may not be of much use in predicting instability towards bodies immersed in them. A more detailed examination of this phenomenon is at present being made.

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Effect of Electric Fields on Hydrogen-like Excitons

Some substances such as cadmium sulphide show long-range photo-effects; that is, if light falls on a crystal at some point then photo-conductivity can be observed in regions which may be several millimetres away from this point. There has been some dispute as to whether excitons play any part in this process of energy transfer[1]. Recently, Nikitine and Haken[2] have shown that the change of energy of an exciton in a magnetic field due to its diamagnetism may be appreciable compared with the thermal energy kT, at least if the field is high and the temperature low. They suggest that if exciton migration occurs then an inhomogeneous magnetic field should have a detectable effect on it.

We wish to point out that the interaction of an exciton with an electric field may be more easily observed. Suppose the exciton is describable in terms of a hydrogen-like s-function. Then it can be shown that in an electric field F its energy is decreased to a first approximation by :

$$\Delta E \simeq -\frac{9}{4} \varkappa a_e^3 F^2 \qquad (1)$$

where $\varkappa$ is the dielectric constant of the crystal and a_e is the effective exciton radius. Since both these quantities can be large, ΔE can be very large. For example, if $\varkappa$ is 10 and a_e is 50 Å. then in a field of 3×10^4 V./cm. the value of ΔE will be equal to the exciton binding energy of 0·014 eV. This means that the perturbation energy is so large that we are already beyond the limit of validity of equation 1 and field ionization of the exciton can occur. The theory of this process for a hydrogen atom has been given by Oppenheimer[3]. Roughly, ionization occurs when the difference of potential energy across the exciton due to the applied field is equal to the binding energy E_b, or :

$$ea_eF_i \simeq E_b \qquad (2)$$

With the parameters used above the threshold field for ionization F_i is 2×10^4 V./cm.

Fields of such magnitude can be applied to a crystal by using external electrodes, but they also arise naturally within the crystal in the potential barriers at grain boundaries. If the density of centres contributing to the space charge in the barrier is 5×10^{16} cm.$^{-3}$ then a barrier height of only 0·1 V. will produce a field of 2×10^4 V./cm. Clearly much higher fields can be produced by applying an external voltage along a crystal containing a transverse grain boundary. The boundary will then attract excitons through the polarization mechanism described by equation 1 and destroy them by the ionization mechanism of equation 2. It will therefore be opaque to excitons but transparent to light, and we have a means of distinguishing between the two.

As an example, we have observed long-range photo-effects in high-resistivity gallium arsenide and have shown that they are entirely unaffected by the presence of a grain boundary. We conclude that in this material the effects are not due to exciton migration. A full account of these experiments will be published elsewhere.

Acknowledgment is made to the Admiralty for permission to publish this communication..

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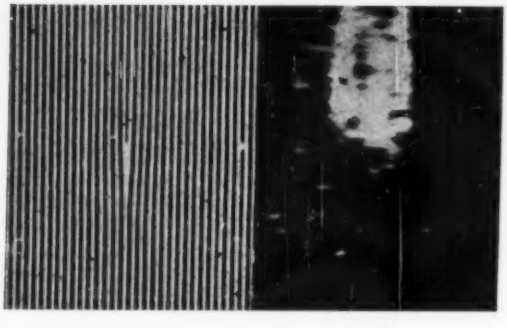
Electron Microscope Images of Dislocations

Hirsch *et al.*[1] and Bollmann[2] observed dark and white spots in the electron microscopic image of thin metallic film, and suggested that the contrast is caused by the Bragg reflexion due to the distorted lattice around a dislocation. We call this, for convenience, *H.-B.* dislocation contrast. Menter[3] first observed an extra terminating half-line in the electron microscope image of platinum phthalocyanine, and suggested that the extra line is the image of the extra terminating half-plane associated with an edge dislocation in the crystal. We call this Menter's dislocation contrast. In Menter's dislocation, no contrast such as *H.-B.* dislocation can be observed.

A plane grating of 66μ spacing was irradiated by an almost parallel light-beam of wave-length 4900 Å. This corresponds to the electron optical system where a thin crystal is irradiated by electrons. Fig. 1*a* is an image of the grating with an extra terminating half-line near its centre which is photographed by allowing the diffracted beams of the order $n = 0, \pm 1, \pm 2$ to contribute to the image. This corresponds to Menter's dislocation contrast. The diffraction pattern of the grating is illustrated in Fig. 2. In a metal crystal, the spacing of the lattice is about a tenth of that of platinum phthalocyanine, and the Bragg angle of the diffracted electron beam is about ten times larger than that of phthalocyanine. In the image of a metal crystal, therefore, only one diffracted beam is permitted to contribute to the image by the small aperture in the objective lens. Fig. 1*b* shows an image of the same grating which is imaged under the conditions where only one part of a diffracted beam $n = +1$ contributes to the image. This corresponds to a dark-field image showing *H.-B.* dislocation contrast. Thus we are able to



(a) (b)

Fig. 1. *a*, Amplitude grating with a dislocation near its centre imaged by allowing the diffracted beams of the order $n = 0$, ± 1, ± 2, to contribute to the image; *b*, the same imaged with a stop in back focal plane of lens to permit only a small part of a diffracted beam to pass through to image plane

Fig. 2. Diffraction pattern of the grating shown in Fig. 1

produce images similar to those taken by Menter and *H.-B.* from the same grating[4].

In the experiment recorded in Fig. 1*b*, if the whole of a diffracted beam contributes to the image, the contrast shown in Fig. 1*b* will never be observed. However, it may be explained that the contrast of dislocation in plane grating is similar to that of *H.-B.* dislocation contrast of a crystal. The intensity of a diffracted beam from a crystal with sufficient thickness changes by the deviation from the Bragg angle. Therefore, the order of deviation can be detected by the variation of intensity of the diffracted beam, that is, brightness of the electron microscopic image. In a very thin crystal, which may be replaced by a plane grating, deviation from the Bragg angle will not produce the variation of intensity because of uniform intensity cross-section of reciprocal lattice point elongated normal to the crystal surface. In a very thin film, the amount of deviation from the Bragg angle can be detected only by the angular deviation of the diffracted beam from the Bragg angle. Therefore, in order to detect the amount of deviation by the variation of intensity of beam, it is necessary to use the very small aperture so that one part only of the diffracted beam can contribute to the intensity of the image.

In a real crystal the diffracted intensity depends on the crystal lattice potential and crystal thickness in addition to the deviation from the Bragg angle, and for a complete interpretation these quantities must be taken into account. The experiment described here does, however, give a useful qualitative interpretation of how these two types of dislocation contrast arise.

We wish to express our sincere thanks to Prof. K. Tanaka for his kind discussion and to Dr. J. Menter for his helpful discussion and for correcting the English.

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METALLURGY

Work-Hardening and Ductility of Rhenium and their Relation to the Behaviours of Other Metals having a Hexagonal Structure

Polycrystalline rhenium work-hardens rapidly when tested in tension at room temperature (the proportional limit is 26,000 p.s.i. and the ultimate tensile strength is 164,000 p.s.i.[1]), and has an elongation of 24 per cent. The fracture is intergranular[2]. In the present communication an extension of the study of the mechanical properties of rhenium to single crystals is reported. The behaviour of rhenium is then compared with other metals having a hexagonal structure.

Crystals grown by the electron bombardment technique[3] were deformed in tension, and the dependence of their behaviour on orientation was studied. Slip occurred on the (0001) basal plane and on the $\{10\bar{1}0\}$ prismatic planes in agreement with earlier work in this laboratory on polycrystals[2]; the slip direction was $<11\bar{2}0>$ as with other close-packed-hexagonal metals which slip on these planes (beryllium, magnesium, titanium and zirconium). For each crystal, the first slip system which became operative was noted; this depends on orientation as shown in Fig. 1. From the position of the boundary AB it is seen that the critical resolved shear stress for (0001) slip is about half the critical resolved shear stress for

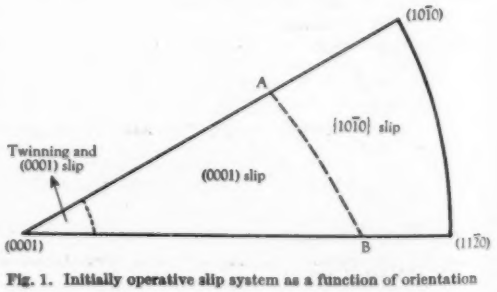

Fig. 1. Initially operative slip system as a function of orientation

{10$\bar{1}$0} slip, the actual values being approximately 1,300 p.s.i. and 2,400 p.s.i. respectively.

All crystals were very ductile with elongations greater than 40 per cent. Specimens oriented with either a <10$\bar{1}$0> or a <11$\bar{2}$0> direction parallel to the tensile axis deformed by duplex {10$\bar{1}$0} slip and necked down to a chisel-edge type fracture. In crystals oriented so that slip occurred initially on only one {10$\bar{1}$0} plane the lattice rotated into an orientation which gave duplex {10$\bar{1}$0} slip, leading to a similar fracture. The work-hardening rate was more rapid for slip on a {10$\bar{1}$0} plane than on the (0001) plane, and when duplex {10$\bar{1}$0} slip occurred the rate was greater still.

In contrast with this behaviour of rhenium crystals oriented with a <11$\bar{2}$0> direction parallel to the tensile axis, similarly oriented beryllium crystals[4] deform by single {10$\bar{1}$0} slip leading to fracture on a {11$\bar{2}$0} plane after elongations of about 10 per cent.

Table 1

Metal	Critical resolved shear stress (p.s.i.)		C.R.S.S. (0001) slip / C.R.S.S. {10$\bar{1}$0} slip	Elongation of polycrystalline metal at room temperature
	(0001) slip	{10$\bar{1}$0} slip		
Beryllium	2,000	9,500	0·21 (ref. 4)	<5 per cent unless of special preferred orientation
Rhenium	1,300	2,400	0·5	25 per cent (ref. 1)
Titanium	9,000	2,000	4·5 (ref. 5)	≃ 50 per cent for iodide titanium (ref. 6)
Zirconium	>4,800	1,300	>3·7 (ref. 7)	≃ 40 per cent for iodide zirconium (ref. 8)

When the behaviours of polycrystalline hexagonal metals which slip on the {10$\bar{1}$0} planes are compared, it appears that the ductility decreases as prism slip becomes more difficult (Table 1). Hauser, Landon and Dorn[9] reached a similar conclusion on comparing magnesium with magnesium base alloys. Such a correlation is compatible with current ideas on fracture; for it is generally believed that for brittle fracture to occur, energy must not be dispersed by plastic flow, and when multiple slip is possible, this dispersion of energy becomes easier.

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Borrmann Effect observed in an Aluminium Single Crystal

In X-ray diffraction studies of a nearly perfect single crystal, Borrmann *et al.*[1] observed anomalous increases in the intensities not only of the diffracted but also of the transmitted ray. This phenomenon was interpreted by Laue[2] from the dynamical theory of X-ray diffraction. Such a dynamical effect on X-ray diffraction, however, has hitherto been observed only on some kinds of natural crystals of good quality. Fortunately, recent techniques are making it possible to obtain substances of high purity, and consequently experimental studies of the dynamical effect are possible without serious difficulty.

In general the crystal structure of a metal single crystal is imperfect, and accordingly the dynamical effect will be negligible. Lately, however, the change in the integrated intensity of X-rays due to cold-working has been examined with aluminium single crystals and a large effect of extinction was observed[3]. This result shows that the aluminium single crystal used was of good quality, and so the abnormal transmission described here might be observable in such cases. Hence the present experiment was carried out to ascertain whether it is possible to see the Borrmann effect in the aluminium single crystal also.

The crystal specimens were made by the following process: aluminium 99·995 per cent in purity, was cold-rolled into strips, approximately 4 mm. in thickness, and after etching and washing, the strips were annealed preliminarily at 500° C. for 2 hr., and after subjecting to 2 per cent elongation they were heated at 600° C. for 150 hr. to produce the single crystals. In the X-ray examination a copper target was used at 15 kV. and 7 m.amp., a nickel filter about 10μ in thickness was inserted, and the beam aperture was of the order of 5°. The irradiated area of the specimen was about 5 mm. in diameter, and the X-ray source was of the order of 1 mm. in diameter. The specimen was mounted on a goniometer and adjusted so as to obtain a (200) reflexion. The glancing angle of the incident ray was about 75° when set at the Bragg angle. An X-ray film, which was masked with a black paper, was placed so as nearly to touch the back surface of the specimen.

In some cases the Borrmann effect could be observed as shown in Fig. 1, from which it will be seen that the image is formed of two irregular intense lines, which are the images of the transmitted and the diffracted rays, respectively. As the X-ray source is, however, comparatively large, the fine structure of the image is obscure. Fig. 2 is a transmission Laue photograph from the region, either surface of which was ground carefully with emery

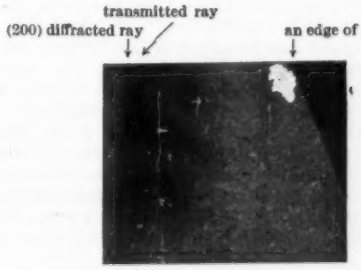

Fig. 1. X-ray image of an aluminium single crystal. (× 10)

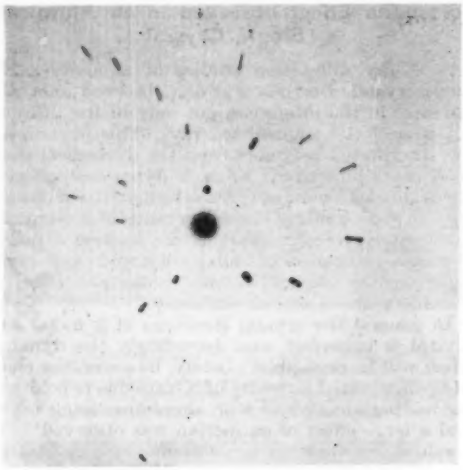

Fig. 2. X-ray photograph of an aluminium single crystal showing double spots

paper. It is clearly seen that each Laue spot is split into two parts. These correspond to an intense reflexion from the thin layer of either surface of the specimen[3]. The observation indicates a large extinction effect. Therefore it may be concluded that the Borrmann effect is also observable in an aluminium crystal of structurally good quality.

We are continuing our studies of the lattice defects of metals by using aluminium single crystals made by zone melting, and are expecting that the internal structure of the crystal will become observable more clearly with such materials of high purity.

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CHEMISTRY

The Silicon–Boron System

Recently the synthesis of a compound of the composition SiB_4 has been reported in two articles[1,2]. Concurrent with this work we have been investigating this compound as a part of our programme for studying high-temperature materials.

The compound was prepared in two different ways: (*a*) by sintering in an argon atmosphere a mixture of finely powdered boron (99 per cent purity) with amorphous silicon in an electrical resistance-type furnace; (*b*) by melting a mixture of boron (about 10 per cent) and silicon (about 90 per cent) in a high-frequency induction furnace in an argon atmosphere. The last method usually gives very beautiful crystals of the new silicon boride (SiB_4) embedded in the silicon phase. The excess silicon was dissolved in a nitric acid–fluoric acid mixture.

By the first method of preparing the compound, we were able to study the behaviour of silicon–boron mixtures under various conditions. We have found that at temperatures between 1,200 and 1,380° C., the new compound is formed at first, but is then slowly decomposed into SiB_6 and silicon. At temperatures below 1,200° C. it is stable for long periods. The pure compound, apparently free from SiB_6 and silicon, has been prepared from the stoichiometric mixture heated at 1,200° C. for about three weeks in an argon atmosphere.

Several of our chemical analyses and density measurements indicate the formula SiB_4 (39·3 wt. per cent silicon). Some of our analyses, however, gave higher values of the silicon percentage (up to 48 wt. per cent silicon) and some density measurements also gave considerably higher values (up to 2·55 gm./cm.^{3}) than the one calculated for SiB_4 from our unit cell data: $a = 6{\cdot}319 \pm 0{\cdot}005$ Å. $b = 12{\cdot}713 \pm 0{\cdot}010$ Å. (2·43 gm./cm.^{3}). (Compare the result of Moissan's investigation[3] of apparently the same compound: formula SiB_3, density 2·52.) This suggests a fairly broad homogeneity range, which is also in accordance with the structural arrangements proposed by us. As a further support of this, we have noticed a small variation in relative line intensities from different samples.

From Weissenberg data a two-dimensional Patterson projection along the hexagonal *c*-axis was carried out. The result bears a close resemblance to the corresponding Patterson synthesis for CB_4 (ref. 4), and it would be reasonable to believe that the two compounds are isostructural. However, there are certain discrepancies, and therefore a three-dimensional Patterson synthesis was carried out. It shows that in the 0,0,*z*-position only two atoms are situated, about 2·4 Å. apart. The other atomic positions form icosahedrons in approximately the same manner as in CB_4. The atoms of an icosahedron are of two different sizes, the atoms forming the top and bottom of the icosahedron having higher electron density than the others.

A reasonable way to interpret these facts is the following. Consider the space group $R\bar{3}m$, formula SiB_4 with 9 molecules in the hexagonal cell. 6 of the 9 silicon atoms are placed in a 6c position, the other 3 silicon atoms and 15 boron atoms are statistically distributed over an $18h_1$ position ($x \approx 0{\cdot}11, z \approx 0{\cdot}87$), and 18 boron atoms are placed in an $18h_2$ position ($x = 1/6,\ z \approx 0{\cdot}02$). The remaining three boron atoms may be placed in interstitial positions or the composition may not be SiB_4. The presumed substitution of boron atoms by silicon atoms in $18h_1$ naturally gives room for a large variation of the composition.

In addition to the work on SiB_4, we have made some preliminary measurements on a part of the liquidus curve of the silicon–boron system. The result is given in Table 1. It is evident that there is a eutectic at about 3 per cent boron.

Table 1. Liquidus Temperatures of Silicon–Boron Mixtures

Weight per cent boron	Temperature of final disappearance of the solid phase (° C.)
0	1,420
1	1,415
2	1,408
3	1,403
4	1,411
5	1,414
6	1,420
7	1,432
8	1,431
9	1,421
10	1,431

The work on this liquidus curve and on the structure of SiB_4 will be continued. A three-dimensional Fourier synthesis is being carried out at the moment and the exact parameters will be published later.

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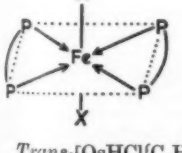
Some New Hydrides of Iron and Osmium

STABLE hydrido-complexes of the type *trans*-$[MHX(\text{phosphine})_n]$ (X = halogen or similar anionic ligand, phosphine = tertiary phosphine or chelate di-tertiary phosphine) containing the heavier transition metals ruthenium[1], osmium[1], palladium[2] and platinum[2] have been reported and a very unstable nickel derivative is also known[3]. Here we report the first stable derivatives containing a metal (iron) from the first transition series. These are interesting because the halo-hydrides (II) and (IV) show enormous chemical shifts in the proton resonance spectrum and because the hydride (I) was prepared from the metal and gaseous hydrogen. They have the *trans*-octahedral structure shown below and their properties are summarized in Table 1.

Table 1. PROPERTIES OF THE COMPLEX IRON HYDRIDES

Compound	m.p. (vacuum)	ν_{Fe-H}	δ_{Fe-H} ('Nujol'	ν_{Fe-D} mulls)	δ_{Fe-D}	Chemical shift (p.p.m., water standard)
(I)	248–252° dec.	1,726(*s*)	716(*m*)	1,259(*s*)	525(*m*)	+18·4 (C_6H_6)
(II)	154·5–155·5° dec.	1,849(*s*)	—	1,336(*s*)	—	+39·1 (C_6H_6)
(III)	180° dec.	1,810(*s*)	—	—	—	—
(IV)	dec. *c.* 220°	1,870(*s*)	—	—	—	+36·0 (C_6H_6)

Trans-$[FeH_2\{o\text{-}C_6H_4(PEt_2)_2\}_2]$ (I) is prepared by dissolving finely divided iron in the diphosphine, $o\text{-}C_6H_4(PEt_2)_2$, at 190° under hydrogen at atmospheric pressure, or by reducing *trans*-$[FeCl_2\{o\text{-}C_6H_4(PEt_2)_2\}_2]$ or $[FeCl_2\{o\text{-}C_6H_4(PEt_2)_2\}_2][FeCl_4]$ with excess lithium aluminium hydride. It is an orange crystalline substance, easily soluble in organic solvents, monomeric in boiling benzene, and thermally remarkably stable but very sensitive to air. The red crystalline hydrido-chlorides (II) and (III) are obtained by lithium aluminium hydride reduction of *trans*-$[FeCl_2(\text{diphosphine})_2]$, while (IV) is made by the reaction of *trans*-$[FeH_2\{o\text{-}C_6H_4(PEt_2)_2\}_2]$ with one equivalent of hydrochloric acid in dry ether.



(I) X = H, P—P = $o\text{-}C_6H_4(PEt_2)_2$
(II) X = Cl, P—P = $C_2H_4(PEt_2)_2$
(III) X = Cl, P—P = $C_2H_4(PMe_2)_2$
(IV) X = Cl, P—P = $o\text{-}C_6H_4(PEt_2)_2$

Trans-$[OsHCl\{C_2H_4(PEt_2)_2\}_2]$, which completes the first eutropic series of phosphino-hydrides, has also been prepared, and a comparison of properties is made in Table 2.

Table 2. SOME PROPERTIES OF *trans*-$[MHCl(C_2H_4(PEt_2)_2)_2]$ (M = Fe, Ru, Os)

M	m.p. (vacuum)	Colour	Dipole moment (±0·2 D)	ν_{M-H} ('Nujol' mull)	Chemical shift (p.p.m., water standard)
Fe	154·5–155·5 dec.	red	4·25	1,849	+39·1 (C_6H_6)
Ru	174·5–176	colourless	4·9	1,944	+27·1 ($CHCl_3$) +26·1 (C_6H_6)
Os	170·5–171·5	colourless	4·6	2,051	+31·3 ($CHCl_3$)

It will be noted that ν_{M-H} increases by 202 cm.$^{-1}$ on passing from M = iron to M = osmium, corresponding to about 24 per cent increase in bond-strength (force constant) on ascending the series. This is also the sequence of increasing thermal stabilities.

The chemical shift of the proton resonance in compound (II) is the largest ever recorded. It is even greater than the shift of the proton resonance in water relative to the unshielded proton (27 p.p.m.).

We are indebted to Dr. N. Sheppard of the University of Cambridge for the nuclear magnetic resonance spectra, to Dr. D. M. Adams for the infra-red spectra and to Miss I. Bates for the dipole moment determinations.

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Gas Liquid Chromatography of Conjugated Fatty Acids

THE heating of polyunsaturated fatty acids in strong alkali is known to cause re-arrangement of the double bonds to form a conjugated system[1]. The effect of this isomerization on the behaviour of polyunsaturated fatty acids in gas liquid chromatography has been studied in relation to linoleic and linolenic acids as found in wheat flour oil.

Oil was extracted by shaking the flour continuously for 2 hr. with carbon tetrachloride under nitrogen. The extract was filtered to remove flour particles and the solvent removed under vacuum in a rotary evaporator. Unconjugated fatty acids were prepared by saponification of the oil under nitrogen with 0·5 *N* methanolic potassium hydroxide, refluxing for 2 hr. Following acidification and ether extraction, the free fatty acids were methylated by reaction with diazomethane[2].

Conjugated fatty acids were prepared by an adaptation of the alkaline isomerization method[3] for analysis of unsaturated fatty acids. The oil was heated in a solution of 6·6 per cent potassium hydroxide in ethylene glycol at 180° C. for 25 min. under a stream of oxygen-free nitrogen. The mixture was cooled, diluted with water and acidified, when the isomerized free fatty acids were extracted with ether. The fatty acids were methylated as before by reaction with diazomethane.

The mixed methyl esters were analysed with a Pye argon chromatograph using a column packed with 2·3 per cent poly(ethyleneglycol adipate) as stationary phase on 60–100 mesh diatomaceous earth (M. and B. 'Embacel'). The chromatograms of the

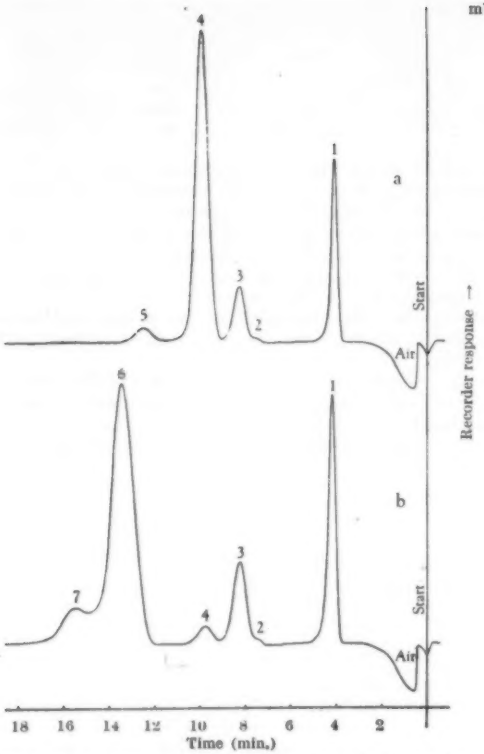

Fig. 1. Gas liquid chromatograms of fatty acid methyl esters from (*a*) unisomerized and (*b*) isomerized wheat flour oil. Column: 120 cm. × 0·4 cm. with argon flow of 20 ml. per min. at 177° C. Peak identification: (1) methyl palmitate; (2) methyl stearate; (3) methyl oleate; (4) methyl linoleate; (5) methyl linolenate; (6) methyl linoleate, conjugated isomer; (7) methyl linolenate, conjugated isomer

methyl esters of the unisomerized and isomerized fatty acids (Figs. 1*a* and *b*) show that following isomerization there is a change in the position occupied by the esters of linoleic and linolenic acids, the conjugated isomers being retained by the stationary phase to a greater extent than the unconjugated acids.

The retention volumes for individual esters, and the percentage composition of the two mixtures are given in Table 1. These results show that isomerization increased the retention of methyl linoleate by 36 per cent, and of methyl linolenate by 24 per cent. The excessive broadening of the conjugated fatty acid ester peaks in Fig. 1*b* may be due to the presence of *cis- trans*-isomerism in the conjugated systems. Such isomerism in a conjugated system has been shown by Hoffmann and Keppler[4] to affect the position of 2,4 decadienals in gas liquid chromatography on a silicone-oil column.

Table 1. Gas Liquid Chromatography Analysis of Isomerized and Unisomerized Flour Oil

Fatty acids (as methyl esters)	Retention vol. (ml.)	Relative retention time (oleic = 1·00)	Percentage composition	
			Unisomerized	Isomerized
Palmitic acid	81	0·50	17·5	19·3
Stearic ,,	149	0·91	0·3	0·3
Oleic ,,	163	1·00	11·3	11·6
Linoleic ,,	195	1·20	65·9	2·9
Linolenic ,,	247	1·51	5·0	—
Conjugated linoleic ,,	266	1·63	—	60·1
Conjugated linolenic ,,	306	1·88	—	6·5

The presence of 2·9 per cent of unconjugated methyl linoleate in the isomerized sample indicated incomplete isomerization of the oil by the method[3] used. This was reflected in the low figure of 60·1 per cent for conjugated methyl linoleate as compared with the presence of 65·9 per cent methyl linoleate in the unisomerized sample. However, the total percentage of polyunsaturated acids in the two samples agreed well (unisomerized 70·9 per cent, isomerized 69·5 per cent) and was within the expected error of a single-run determination.

The effect of isomerization on the position of these unsaturated acids when analysed on a column having 5·9 per cent 'Apeizon *L*' grease as stationary phase was also examined. With this type of column the order of elution of saturated and unsaturated fatty acid esters is the reverse of that found using the polar polymer stationary phase mentioned above; that is, increasing unsaturation shortens the retention time of acids having equal carbon chain-lengths.

As previously found[5], the retention time of the polyunsaturated acids was increased after isomerization. The retention time for methyl linoleate increased by 27 per cent, and for methyl linolenate by 58 per cent. This change was particularly striking since before isomerization the unsaturated acids were not separated by this column, whereas after isomerization methyl linoleate was completely separated from methyl oleate, although its position was now coincident with that occupied by methyl stearate.

The marked change in retention time of polyunsaturated acids following isomerization demonstrates the importance of using mild conditions for the saponification of lipids containing such acids during the preparation of the free fatty acid esters for gas liquid chromatography. Thus, inadvertent formation of conjugated acids during the saponification procedure is likely to give rise to anomalous peaks on the chromatograms which will affect both the qualitative and quantitative analyses of the acids present.

In view of this possibility when using the saponification procedure, an alternative method of preparing lipid material for gas liquid chromatography analysis is perhaps to be preferred. Inter-esterification with dry methanol in the presence of an acid, followed by extraction and high-vacuum distillation of the methyl esters formed[6], is one such method, and is now being used exclusively in this laboratory.

We wish to thank Mr. R. J. Davies for technical assistance in this work.

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RADIOCHEMISTRY

Radiolysis of Highly Enriched Oxygen-18 Water Solutions containing Hydrogen Peroxide-16,16

THE use of the isotope oxygen-18 opens new possibilities to gain information regarding the primary processes in irradiated aqueous solutions. Using ordinary water in the presence of oxygen-16,18, Hart, Gordon and Hutchison[1] were able to obtain information regarding some of the reactions of molecular oxygen. Backhurst, Johnson, Scholes and Weiss[2], using water enriched 1·5 mol. per cent in oxygen-18 at *p*H 1·2, were able to investigate the incorporation of oxygen-18 into the hydrogen peroxide formed. Recently, highly enriched (92–95 atom per cent oxygen-18) water became available prepared in the Isotope Distillation Plant of the Weizmann Institute and contained practically 100 per cent deuterium), which enables one to investigate the fundamental processes involved, and high concentrations of hydrogen peroxide-16,16 itself may be used to protect the hydrogen peroxide formed by various mechanisms, while serving as a scavenger of radicals at the same time.

We investigated the action of 200-kVp. X-rays and 2·9-MeV. protons on solutions of approximately 1 *M* hydrogen peroxide-16,16 in water, which contained 92–95 atom per cent oxygen-18.

Reactions were carried out in the presence and absence of initially added oxygen-16,16 or oxygen-18,18 (94 per cent) and in the presence or absence of added 1 *M* bromide. The reaction products investigated were oxygen-16,16, oxygen-16,18 and oxygen-18,18 formed during radiolysis as well as the same species formed from the decomposition of the hydrogen peroxide after irradiation was completed. Hydrogen peroxide was decomposed by platinum-black, which has been shown (Anbar, M., unpublished work) not to produce during decomposition any induced exchange between the various isotopic species of hydrogen peroxide. Hydrogen peroxide also does not appreciably exchange its oxygen with water. The presence of a high concentration of hydrogen peroxide protects the hydrogen peroxide formed during irradiation, the isotopic composition of which remains intact, and enables its total yield and mode of formation to be investigated.

It was found that in the case of X-rays the yield of hydrogen peroxide-18,18 is relatively unaffected by added bromide ions; the yield is proportional to dose up to total doses of 2 Mrads, the *G* value being approximately 0·4. On the other hand, in the case of proton irradiation, the yield of hydrogen peroxide-18,18 is reduced by a factor of nearly 10 when bromide is present during irradiation.

The yield of hydrogen peroxide-16,18 in a solution irradiated with X-rays is reduced to half in the presence of bromide, and to one-tenth when proton irradiation is used. For X-rays, the yield of hydrogen peroxide-16,18 remains approximately constant in the *p*H range 0·3–11. That of hydrogen peroxide-18,18 decreases very significantly above *p*H 8. These results point to different mechanisms for the formation of hydrogen peroxide-18,18 and hydrogen peroxide-16,18. Tracer experiments using originally added oxygen-18,18 proved that hydrogen peroxide-18,18 does not originate to any large extent from this source. In addition to the radical intermediates H and OH formed from the water by the radiations[3], it is assumed that molecular products, H_2 and H_2O_2, may be produced directly from water[4].

Our results show that hydrogen peroxide-18,18 can indeed be formed through a distinct 'molecular' mechanism from water alone, whereas 'scrambled' hydrogen peroxide-16,18 results from reactions of $H^{18}O$ radicals or their equivalent with hydrogen peroxide-16,16, according to:

$$^{16}OH + H^{18}O - {}^{16}OH \rightarrow H^{18}O - {}^{16}OH + {}^{16}OH$$

Full details of this work are being prepared for publication.

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Non-destructive Analysis of Microgram Quantities of Silver by Radioactivation

A NON-DESTRUCTIVE method of determining μgm. quantities of silver by use of the nuclear reactor *JRR*-1 and an *RCL*-256-channel pulse-height analyser has been investigated.

In the present work, a sample (0·1–10 gm.) is placed in the reactor for 30 sec. to be irradiated with neutrons at a flux of 3×10^{11} neutrons per sq.cm./sec., cooled for 10 sec., counted for 20 sec., further cooled for 10 sec., and counted for 20 sec. The scintillator used is a 2-in. thick, well-type sodium iodide crystal. An aluminium vessel (2·5-mm. thick) is inserted in the well as an absorber for β-rays. At the first counting 128 channels in the analyser are used, and in the second counting the rest are used. The resultant γ-spectrum shown on the monitor (Braun tube) is photographed and the height of photopeak due to 0·66 MeV. γ-rays with silver-110 ($T_{1/2} = 24·2$ sec.) is measured. By the comparative method the amount of silver is determined.

An example of the coefficient of variation of single analyses has been obtained by the use of six standard samples which include 1·25 μgm. of silver each. The coefficient estimated from six values is only 2·8 per cent, the average area under photopeak being $3·4 \times 10^3$ counts. Results of analysis are shown in Table 1.

In the case of lead, interference is negligible. In the case of bismuth, slight interference due to *Bremsstrahlung* is found. In the case of zinc sulphide, though two

Table 1. RESULTS OF ANALYSIS

Sample	Silver found (p.p.m.)
Lead	1·09
Bismuth I	7·6
Bismuth II	< 0·02
Zinc sulphide (silver added)	22·2

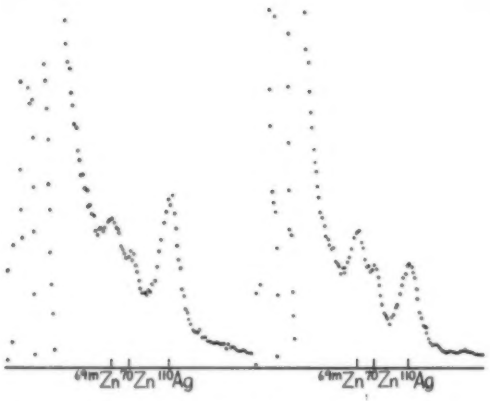

Fig. 1. γ-Spectrum. Sample: 0·3 gm. of silver-added zinc sulphide

photopeaks due to 0·438 MeV. γ-ray with zinc-69 *m* and 0·513 MeV. γ-ray with zinc-71, respectively, are found, the extent of interference is small (Fig. 1). From this the lower limit of the detection of silver in zinc sulphide is estimated at about 1 p.p.m. Further, it can be deduced that, if the matrix of a sample is made of an element which is less activated than zinc under the conditions described above, the detection limit of silver is less than 1 p.p.m. Such elements have been found in the literature on the basis of activation cross-section, half-life of nuclide formed, abundance of unconverted γ-photons of nuclide formed, and of neutron absorption cross-section, and are shown in Table 2.

Table 2. Elements in which the Detection Limit of Silver is Less than 1 p.p.m.

(Arranged by increasing γ-activity to be induced under conditions in this work)

H	He	Be	C	N	Pb	Bi
Ne	O	Zr	S	Tl	Y	Ce

I hope to publish a full account of this work in the *Nippon Kagaku Zasshi* (*Journal of the Chemical Society of Japan*).

I am indebted to Prof. Shoji Makishima for encouragement, and to Dr. Toshio Nakai for permission to use laboratory facilities. My thanks are also due to Dr. Seishi Yajima, Dr. Yuichiro Kamemoto, Mr. Koreyuki Shiba and Mr. Terutomi Moki for their help with the γ-spectra.

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Radiolytic Oxidation of Ferrous Solutions with Standardized Internal Sources of Phosphorus-32

The 'Fricke' solution is the most common chemical dosimeter in use at present, but the G-value of the oxidation is still not universally accepted. We have redetermined this value by radiolysis with 100–350 mc. phosphorus-32 dissolved in air-saturated 0·8 N sulphuric acid containing 10^{-3} M ferrous ions (as ferrous ammonium sulphate) and 10^{-2} M chloride (as sodium chloride). The energy dissipated by the radioactive decay was determined from standardization of the radioactivity by 4π-proportional counting as well as 4π-liquid scintillation counting, and an acceptance of the calculated value[1] of 0·69 MeV. for the average energy per disintegration of phosphorus-32.

The standardization values as obtained by the 4π-liquid scintillation method are about 1·1 per cent higher than those from 4π-proportional counting. This discrepancy is consistent and quite reproducible[2]. For some years now it has been believed that the proportional counting method was very nearly 100 per cent efficient for high-energy beta emitters such as phosphorus-32 [3], but recent work[4] using sodium-24 and phosphorus-32 incorporated in the same compound, $^{24}NaH_2{}^{32}PO_4$, in which each radionuclide was separately standardized, the former by β–γ coincidence and the latter by 4π-proportional counting, showed that the self-absorption correction for phosphorus-32 amounted to about 1 per cent. It is thus possible that the newer 4π-liquid scintillation method may be more accurate than 4π-proportional counting.

Carrier-free phosphorus-32, produced by neutron irradiation of sulphur, contains some phosphorus-33. The relative amounts of the two isotopes were determined by measuring the radioactivities of the lines corresponding to mass-charge ratios between 47 and 51 as obtained by the isotope separator of the National Physical Research Laboratory, Pretoria. The phosphorus-33 content was 1·6 ± 0·16 per cent of the total activity.

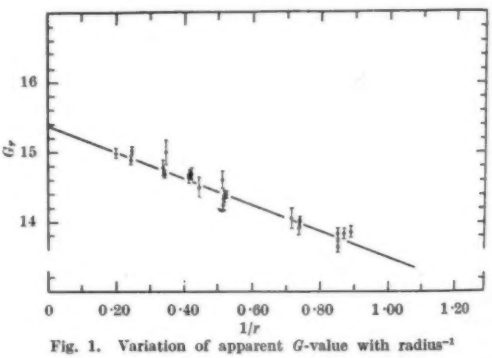

Fig. 1. Variation of apparent G-value with radius^{-1}

Corrections for the loss of energy through the walls of the containers were made by measuring the apparent yield, G_r, for each of 22 spherical glass containers of radius r and extrapolating the plot of G_r against $1/r$ to zero. Fig. 1 shows the results obtained (standardization by proportional counting). The errors marked are standard errors for each flask, and the straight line is that calculated by the method of least squares, each point being given a statistical weight in accordance with the number of replicate determinations made with the corresponding flask. The same data were used to determine the '95 per cent error' of the G-value at infinite radius. The results obtained were:

for 4π-proportional counting	15·39 ± 0·04 ions/100 eV.
for 4π-liquid scintillation counting	15·21 ± 0·04 ions/100 eV.

The assumption of linearity of G_r with $1/r$ is justified by the fact that the discrepancies between values

obtained from the straight line and those calculated from data published by Hine and Brownell[1] lie within the experimental errors.

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BIOCHEMISTRY

Oxidative Phosphorylation: Synthesis of Adenosine Diphosphate by the Oxidation of Quinol Phosphates

The importance of oxidative phosphorylation in the respiratory chain of living organisms has led to intensive research into the possible *in vivo* and *in vitro* mechanisms of phosphorylation[1], and several theories have been advanced which postulate quinol phosphates[2–4] (or analogous nitrogenous systems derived from riboflavin[5,6]) as the active intermediates in phosphate transfer.

An earlier communication from this Laboratory[4] reported the formation of inorganic pyrophosphate during the oxidation of 2-methyl naphtha-1 : 4-quinol diphosphate in aqueous solution in the presence of orthophosphate, and this work has now been extended to the synthesis of adenosine diphosphate. Two routes have been successfully followed, in one of which phosphate has been transferred to adenylic acid as substrate, and in the other the nucleotide has been transferred to inorganic phosphate as substrate.

In the first of these two syntheses of adenosine diphosphate, 2 : 3-dimethyl naphtha-1 : 4-quinol monophosphate was oxidized by bromine in the presence of the tetra *n*-butyl ammonium salt of adenosine-5′-phosphate under rigorously anhydrous conditions in N,N-dimethyl formamide. After removal of excess bromine by *cyclo*hexene and evaporation of the solvent, the residue was dissolved in water and passed down a cation-exchange column ('Amberlite *IR*-120', H^+ form). The eluate and washings were freeze-dried, the residual gum dissolved in ethanol, and the nucleotide fraction precipitated with ether[7]. Repetition of this procedure removed ortho- and pyrophosphate. The nucleotide fraction was chromatographed on an anion-exchange column ('Dowex-1', Cl^- form) and the adenosine diphosphate isolated as the free acid (yield estimated spectrophotometrically, 25 per cent). The product had the correct analysis, a phosphorus to nitrogen ratio of 1 : 2·51, and ran as a single spot during paper chromatography and paper electrophoresis. An enzymic estimation (on a sample which had been kept for a week) using phospho-enol pyruvate-pyruvate kinase and myokinase showed the sample to contain 72 per cent adenosine diphosphate and 28 per cent adenylic acid. A parallel assay on the sodium salt of adenosine diphosphate supplied by the Sigma Chemical Co., St. Louis, Missouri, gave values of 87 per cent adenosine diphosphate and 13 per cent adenylic acid.

In the second synthesis, a naphtha-1 : 4 quinol ester of adenylic acid was oxidized in the presence of inorganic phosphate. Adenosine diphosphate was again isolated as the free acid and assayed as before. The results obtained in the two syntheses were virtually identical.

Further details of this work will appear elsewhere. We are indebted to Dr. K. J. M. Andrews (Roche Products, Ltd.) for helpful discussion and the provision of certain materials, and to Dr. J. B. Chappell (Department of Biochemistry, Cambridge) for the enzymic assays.

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N-Terminal Amino-Acids of Bovine Antibody

Bovine γ-globulin has been shown to be a mixture of molecules having N-terminal amino-acids, aspartic acid, glutamic acid, serine, alanine and valine with a total of less than 1 mole/mole of γ-globulin[1]. A partial fractionation was achieved by partition chromatography of γ-globulin; the molecules with N-terminal aspartic acid, serine and alanine were concentrated in the faster running fractions, but valine, the principal N-terminal acid, was present in all the fractions[2]. Glutamic acid was present in only trace amounts in all the fractions.

In view of these results, we suggested that there were two types of γ-globulin: (1) with N-terminal aspartic acid, serine and alanine; (2) with N-terminal valine, and that a partial fractionation of these two types had been obtained. McFadden and Smith[1] analysed γ-globulin from a cow which had been strongly immunized with mixed antigens and found a much higher content of N-terminal valine and only traces of other amino-acids.

This led us to suggest that antibody γ-globulin had only N-terminal valine, and that the molecules with the other N-terminal amino-acids were really β-type globulins which have an electrophoretic mobility similar to that of antibody. We also found that true β-globulin had N-terminal aspartic acid, glutamic acid, serine, alanine, threonine, but no N-terminal valine.

The gift of bovine antibody to a well-characterized antigen (rabbit serum albumin) by Drs. F. J. Dixon and W. O. Weigle enabled us to test our suggestion. The bovine antibody was received as a freeze-dried specific precipitate prepared from the colostrum of an immune cow. It contained 19 per cent of rabbit serum albumin. Rabbit albumin was found to have glutamic acid as N-terminal amino-acid, present in 0·6 mole/mole albumin. The N-terminal amino-acids of the specific precipitate, after allowance for

Table 1. N-Terminal Amino-Acids in Bovine γ-Globulin

	Amount of N-terminal amino-acid mole/mole protein	
	Commercial preparation	Antibody
Aspartic acid	0·12	0·04
Glutamic acid	0·03	0·00
Serine	0·12	0·10
Alanine	0·11	0·10
Valine	0·45	0·25
Total	0·81	0·49

the N-terminal glutamic acid present in the antigen, are given in Table 1 together with a parallel determination of the N-terminal acids of bovine γ-globulin (Armour Laboratories preparation).

The results for the commercial preparation of bovine γ-globulin agree well with previous results[2] and it can be seen that the N-terminal amino-acid content of the antibody is almost equally complex. Glutamic acid is apparently absent, after allowing for the contribution of the rabbit albumin present in the specific precipitate, but the other four terminal acids are present, all in somewhat lower amounts.

These results do not support the previous suggestion that the complexity of N-terminal amino-acids of bovine γ-globulin arise from contamination with biologically unrelated β-type globulin. The low total yield suggests that in half the molecules the peptide chains are cyclic, or that certain structural features prevent the reaction of the fluor-dinitrobenzene with the terminal amino-group.

We wish to thank Drs. Dixon and Weigle for their generous gift of bovine antibody, and Mr. M. C. Scrutton for his valuable assistance.

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Action of Nucleic Acids on the Inhibition of Growth by Actinomycin of *Neurospora crassa*

Actinomycin is well known to possess cytostatic properties in mammalian tissues[1]. Foley *et al.*[2] have shown the inhibitory effect of actinomycin on the cell-growth of 12 microbiological systems under various experimental conditions. In our work on the mode of action of actinomycin, *Neurospora crassa* was used as test organism.

Recently, Beers[3] has shown the inhibitory effect of dyestuffs on the synthesis of polyadenylic acid in *M. lysodeikticus*. The mechanism of inhibition is supposed to be due to the formation of dye–polymer complexes. Steiner and Beers[4] were able to demonstrate formation of dye–polymer complexes between dyestuff, polynucleotides and yeast ribonucleic acid and deoxyribonucleic acid. An interaction between dyestuff and deoxyribonucleic acid was also shown by Lawley[5]. These findings suggest that actinomycin may act in the same way. It therefore seemed to be of interest to us to study the action of deoxyribonucleic acid, ribonucleic acid and polynucleotides on the growth inhibitory effect of actinomycin on *N. crassa*.

The materials used were: actinomycin *C* from Bayer, Leverkusen; actinomycin *D* from Merck, Sharp and Dohme; deoxyribonucleic acid of low molecular weight from Th. Schuchardt, Munich = deoxyribonucleic acid I; deoxyribonucleic acid of low molecular weight from C. Roth, Karlsruhe = deoxyribonucleic acid II; deoxyribonucleic acid of high molecular weight from C. Roth, Karlsruhe = deoxyribonucleic acid III; ribonucleic acid from C. Roth, Karlsruhe, Th. Schuchardt, Munich, and C. F. Boehringer, Mannheim.

Growth of *N. crassa* was followed in horizontal tubes according to Ryan, Beadle and Tatum[6] (for further details see Rauen[7]). The test-medium was: Fries minimal, *p*H 6·3; concentration of actinomycin 5 μgm. ~ 0·0025 μmol./ml.; growth inhibition at 96 hr. 90 per cent hydrolysis of deoxyribonucleic acid and ribonucleic acid was performed as described by Schmidt[8].

Table 1. Reversal of Inhibition of Actinomycin by Deoxyribonucleic Acid (DNA), Ribonucleic Acid (RNA) and Some of their Degradation Products

Treatment	Substance	Reversal of inhibition (μgm./ml.) 50 per cent	100 per cent
None	DNA I	50	200
	DNA II	30	80
	DNA III	25	60
0·1 *N* hydrochloric acid 20° 4 hr. = intermediaries between DNA and apurinic acid	DNA I	50	200
	DNA II	30	100
	DNA III	25	60
1 *N* sodium hydroxide 20° 18 hr. = acid insoluble polynucleotides	DNA II	25	60
0·1 *N* hydrochloric acid 37° 27 hr. = apurinic acid	DNA II		no effect
Deoxyribonuclease = 5′-oligonucleotides + 5′-mononucleotides	DNA II	60	200
1·5 *N* hydrochloric acid 100° 1 hr. = purines, pyridine-nucleotide diphosphate, pyrimidine-mononucleotides	DNA I		
	DNA II		no effect
	DNA III		
None	RNA	600	
1 *N* sodium hydroxide 20° 18 hr. = (2)3-mononucleotides	RNA	1,200	
0·1 *N* hydrochloric acid 37° 18 hr. = pyrimidine nucleotides	RNA	1,400	
1·5 *N* hydrochloric acid 100° 1 hr. = purines + pyrimidine + (2)3-mononucleotides	RNA		no effect

As shown in Table 1, deoxyribonucleic acid and ribonucleic acid and some of their degradation products, presumably oligonucleotides, counteract the growth-inhibitory action of actinomycin on *N. crassa*. There are some differences between deoxyribonucleic acid of various origins and of various molecular weights. Obviously ribonucleic acid is far less effective than deoxyribonucleic acid. The degradation products of deoxyribonucleic acid and ribonucleic acid, after alkaline and weak acid hydrolysis, are of about the same activity as deoxyribonucleic acid and ribonucleic acid themselves. Degradation products of nucleic acids of low molecular weights, as are found by extensive hydrolysis, are ineffective. It is, however, of interest to note that commercially available purines and pyrimidines in high concentrations (referring to actinomycin) abolish more or less the cytostatic properties of actinomycin. Adenine, adenosine and adenosine mono-, di- and tri-phosphates at concentrations of 1 μmol./ml. reverse the effect of actinomycin to about 50 per cent, 4–5 μmol./ml. to about 100 per cent. Guanine, xanthine and hypoxan-

thine could not be tested quantitatively on account of their weak solubility. Guanosine and inosine were as effective as adenosine. At a concentration of 4–5 μmol./ml., certain unphysiological purine derivatives, for example, 8-azaxanthine and 8-chloroxanthine, also counteract the actinomycin effect in this organism to an extent of 50 per cent. The pyrimidines were found to be not very effective. With 10 μmol./ml. of thymine, cytosine and uracil each, only 30 per cent release of actinomycin inhibition was attained. It was further observed, strangely enough, that some unphysiological pyrimidine derivatives, for example, 5-bromuracil and 2-amino-4-methylpyrimidine, which themselves have cytostatic properties, counteract the actinomycin inhibition to a greater or lesser degree.

These experimental results apparently lead to the suggestion that actinomycin reacts directly with deoxyribonucleic acid, oligonucleotides of deoxyribonucleic acid and to a much lesser extent with ribonucleic acid perhaps by formation of dye–polymer complexes. The effect of purines and pyrimidines is supposed to be a kind of displacement of actinomycin from its site of action in the living cell. The high concentrations required of these substances is evidence in favour of this view.

How far this interpretation of experimental results is relevant must be established by further investigation.

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Biogenesis of Ascorbigen, 3-Indolylacetonitrile and Indole-3-carboxylic Acid from D,L-Tryptophan-3-^{14}C in *Brassica oleracea* L.

During earlier work we found that ascorbigen (the bound form of ascorbic acid) is an indole derivative[1–5]. In view of the fact that the indole moiety of ascorbigen possesses a carbon skeleton identical with that of tryptophan, the hypothesis was put forward that this amino-acid[3], as well as 3-indolylpyruvic acid[6], may be the precursor of the synthesis *in vivo* of ascorbigen. In preliminary experiments we found that the level of ascorbigen in kohlrabi was raised after the injection of tryptophan into the bulb[7].

Jones and co-workers[8] have advanced the theory that 3-indolylacetonitrile, the plant growth stimulator (auxin) in the genus *Brassica*, may also be synthesized *in vivo* from tryptophan.

In order to verify these hypotheses and preliminary observations, we introduced 5·1 mgm. of labelled D,L-tryptophan-3-^{14}C (specific activity, 25·6 μc./mgm.) to the over-ground parts (50 gm.) of young plants of *Brassica oleracea* L., var. *sabauda* (Savoy cabbage). Tryptophan was administered in the form of a concentrated aqueous solution, which was taken up by the plants in the course of 3 hr. The plants were then transferred to a container with distilled water, where they were left for 48 hr. in light, and at a temperature of 25°. The plant juice (20 ml.) was extracted with 10 ml. of light petroleum, in order to eliminate paraffins and waxes[6], and four times with 10 ml. of ethyl acetate. The ethyl acetate extract was evaporated to dryness *in vacuo* and chromatographed on Whatman No. 1 paper with the butyl acetate/water system[1]. The measurement of the chromatogram on a flow counter with automatic registration showed that the R_F-value of the most active zone corresponded to the R_F-value of ascorbigen (0·5). Another zone of activity was found in the range of R_F-values from 0·7 to 1·0 (Fig. 1).

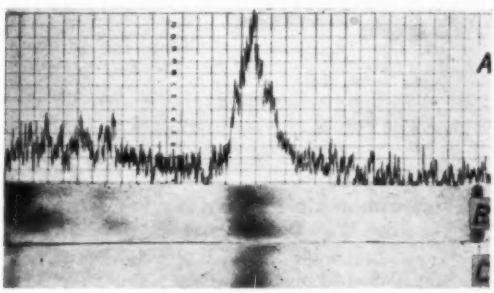

Fig. 1. (*A*) Distribution of the radioactivity on chromatogram *B* as measured with an automatic recording and scanning device (methane flow counter). (*B*) Chromatogram of ethyl acetate extract. (*C*) Chromatogram of a sample of pure ascorbigen

The zone of maximum radioactivity (R_F 0·5) was eluted, and the eluate treated with 1 per cent sodium hydroxide solution. The solution was re-chromatographed in the same solvent system as before. It was found that the eluted active substance behaved in the same way as ascorbigen[9,10], that is, it decomposed into a number of degradation products. The activity in the 0·5 R_F-zone (ascorbigen) disappeared, but reappeared again in the zones of the following R_F-values: 0·9, 0·15 (substance *C*, see refs. 5, 9, 10) and on the starting-line (substance *S*, refs. 10, 12).

The eluate of the zone R_F 0·7–1·0 from the first chromatogram was re-chromatographed in the system carbon tetrachloride/acetic acid/water[3,9,11] and *iso*-propylether/water[11]. Comparison with synthetic specimens showed that the eluate contained radioactive 3-indolylacetonitrile, indole-3-carboxylic acid and a substance corresponding to 3-indolylpyruvic acid. Some other non-identified active products were found in the extract as well.

From these experiments, the conclusion may be drawn that tryptophan can be utilized in the genus *Brassica oleracea* L. for the synthesis of a series of physiologically important indole derivatives, namely: ascorbigen, 3-indolylacetonitrile, indole-3-carboxylic acid and other derivatives.

Our results point to the possibility of a biosynthetic approach to the preparation of labelled ascorbigen that could be of considerable use in the study of its fate and role in plant and animal organisms.

Experimental details will be described in the *Collection of Czechoslovak Chemical Communications*.

We are greatly indebted to Academician F. Šorm for his support and interest during this work.

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Electrophoretic Pattern during Amphibian Development

Paper electrophoresis became a suitable technique for embryological purposes when Kohn[1] proposed the use of pure cellulose acetate as a supporting medium instead of filter paper. This method enables us to separate much smaller amounts of protein than hitherto: one single amphibian embryo yields enough protein to give a clear electrophoretic pattern.

Individual embryos of *Triturus alpestris* of every stage from the uncleaved egg to stage Gläsner 26 were sucked up into a capillary tube, frozen, thawed and centrifuged at 7,000*g* for 20 min. The clear supernatant minus the fat layer was applied as a thin line across a cellulose acetate strip (10 cm. × 5 cm.). The same veronal buffer *p*H 8·6 (0·05 *M*) was used for the extraction of the proteins and for the electrophoresis itself. A potential gradient of 10 V./cm. was applied for 45–90 min. After the run, the proteins were stained with very dilute (1/10,000) nigrosine in 3 per cent trichloracetic acid.

The uncleaved egg yields eleven distinct nigrosine-positive bands. Five of them are on the positive side of the pattern and six on the negative side. This distribution is, however, artificial because of the electro-endosmosis which shifts the starting line towards the negative pole. After correction, it is found that only one band migrates towards the negative and nine towards the positive pole. In cleaving eggs, two new fast electropositive bands appear. These fade away at the blastula stage. During gastrulation and neurulation, the electrophoretic pattern is practically the same as in the uncleaved egg. At the tail-bud stage, two of the strongest bands (the third and the fourth from the positive pole) become progressively reduced and finally disappear. At the same place, two very narrow bands make their appearance and remain to the last stage examined (stage 26). These results are summarized in Fig. 1, which shows the fate of the different protein bands during development.

Spiegel[2], using paper electrophoresis followed by staining with bromphenol blue, could detect six cathodic and one or two anodic bands in *Rana pipiens* embryos. All the fractions were detectable from the unfertilized egg to stage 17 and no new band appears during development. The discrepancy with our results may be explained by the superiority of cellulose acetate over filter paper as a supporting medium.

Chemical tests have been made to determine the nature of the proteins separated by electrophoresis. The periodic acid–Schiff reaction of Köiw and Gronwall[3] as modified by Sohar, Bossak and Adlersberg[4] stains red the second, third, fourth and fifth band (Fig. 1, *b*, *c*, *d* and *e*) of the pattern. Furthermore, there is another strong red band on the positive side of the pattern (between *j* and *k*), but this one does not correspond to any protein band. It consists of polysaccharide (very likely glycogen) shifted towards the negative pole by the endosmotic flow. The first, second, third and fourth bands (Fig. 1, *a*, *b*, *c* and *d*) are strongly basophilic: methylene blue stains them dark blue at *p*H 3.

Attempts are now being made to characterize the chemical nature of all the bands of the embryonic pattern more precisely and to study the distribution of the proteins within different tissues. I wish to thank the Fonds National de la Recherche Scientifique (Belgium) for financial support of this work. I am grateful to Prof. C. H. Waddington for advice and guidance.

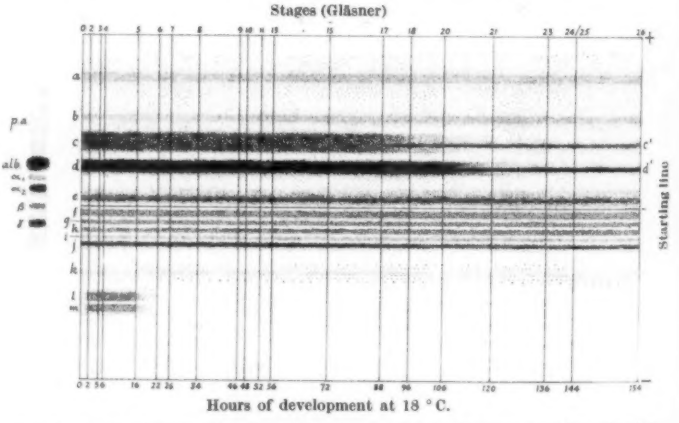

Fig. 1. Electrophoretic changes during embryogenesis. Embryonic proteins subjected to electrophoresis in veronal buffer *p*H 8·6 for 1 hr. at 10 V./cm. Length between electrodes, 8 cm. The starting line is shifted towards the negative pole by the electro-endosmosis. Real neutral point between *j* and *k*. Control of mouse serum in parallel

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PHYSIOLOGY

Electrophysiological Observations on a Sound-producing Fish

SIMULTANEOUS sound and action potential records have been made from a New Zealand marine teleost, *Congiopodus leucopaecilus* (Perciformes), the pigfish, which produces noises in the water by resonance of the swimbladder. The muscles responsible for the sound are a pair of delta-shaped intracostal striated muscles running obliquely between the vertebral intercentra and back border of the pectoral girdle of either side of the body, and lying against the side walls of the swimbladder. In a fish 24 cm. long the swimbladder is 4·5 cm. and the muscles 3 cm.

The records were made on the two beams of a double-beam oscilloscope, the top beam recording the action potentials from a platinum electrode touching the surface of the exposed muscle, and the bottom beam recording the wave form of the sounds in air from a crystal microphone (of the type used in hearing aids) placed against the opposite side of the body. The fish was mounted on a block of wood and perfused through the mouth with aerated seawater.

The records show the expected correlation between the moment of muscle contraction and the onset of the sound produced. They were obtained without artificial electrical stimulation of any kind, and from behaviour observations and tape recordings of the fish in aquarium tanks can be taken as representing the normal pattern of sound production in this fish. Each sound may be thought of as a single drum beat, and they occur singly or at intervals of more than a second, or as a train of beats at rates of 4–10 per sec. when their function probably includes that of threat. These repetitive sounds are accompanied by raising of the dorsal fin armed with stout spines, and dissection reveals that the occipitospinal nerve supplying the drumming muscle also has fibres running dorsally to the spine-raising trunk musculature.

The muscle spike is of extremely short duration and consists of a number of summed muscle action potentials. Fig. 1 shows the recruitment of fibres during the first 6 beats in a train; the synchrony of firing of the different motor units is such that the total duration of the summed spike is increased by less than 25 per cent of the initial one.

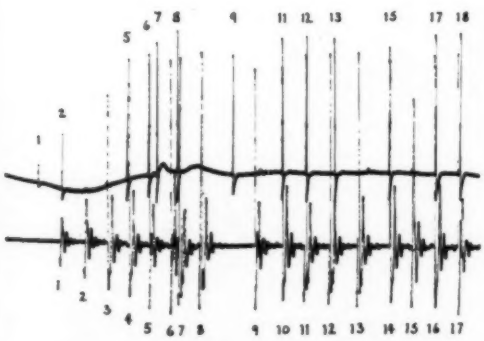

Fig. 1. Muscle action potentials (top trace) and sound vibrations (lower trace) recorded by moving-film camera during the start of a train of sounds at an average of 8/sec. The two beams were staggered in position: the first sound corresponds to the first muscle spike, etc.

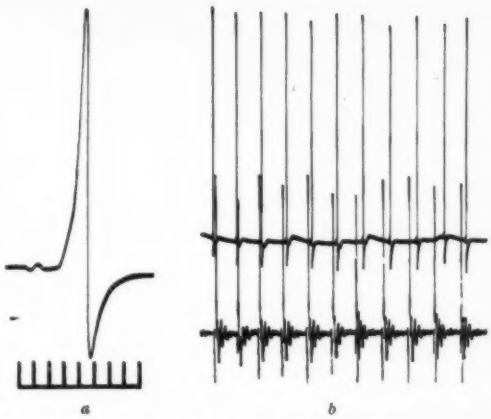

Fig. 2. *a*, Typical summed muscle action potential preceded by the incoming nerve volley (scale in msec.): *b*, record similar to Fig. 1 (but with altered gains) made during a prolonged burst of drumming

The electrical events associated with each contraction (Fig. 2*a*) last 9 msec. The initial deflexion in Fig. 2*a* is the incoming motor nerve volley recorded in volume. The muscle spike, arising after a neuromuscular delay of 1·4 msec., has the following characteristics: rising phase, 2·1 msec.; rapid downward phase, 0·5 msec., and relatively slow (6 msec.) return to resting level from the positive side of the base-line. The end-plate potential appears as a shallow slope (1·1 msec.) at the beginning of the rising phase. Recorded summed spike values are of the order of 6 mV.

There is synchrony of contraction between the drumming muscles of either side. Occasionally during recording one of the two muscles would fail to contract; when this occurred with the exposed muscle, the action potential of the other could still be seen on the recording side and the sound was still maintained (in Fig. 1, the third, fourth, tenth, fourteenth and sixteenth drum-beats are of this kind); in these instances the sound vibrations showed a less-complicated and more-consistent wave-form than when the muscles of both sides contracted. Analysis of the wave-form of the sounds indicates that a 25-cm. fish produces a frequency of about 200 cycles per sec.

It has thus been possible to investigate an overt piece of fish behaviour at a basic physiological level, and it is to be hoped that further features of the behaviour on one hand and its nervous basis on the other will be studied in this preparation. The intracostal muscles of *Congiopodus* and the pattern of impulses they receive from the central nervous system are highly specialized for sound production. The rapidity and constancy of the twitch contraction ensure the production of a specific sound of fairly regular wave-form, though the constancy and loudness of the signal must be limited by the restricted properties of the swimbladder as a resonator. Within these limitations it would seem, both from the steady maximum recruitment-level recorded (Fig. 2*b*) and the fact that the observed rate of drumming is many times slower than the refractory period of the muscle, that the system achieves a near optimal and consistent signal relatively free from interference by a preceding drum-beat. In each of the drum-beats illustrated, except the sixth in Fig. 1, the vibrations of the swim-

bladder recorded in air have almost completely disappeared from the lower trace before the onset of the next beat. Interference is clearly seen in the seventh drum-beat.

Finally, the cerebellum is notably much larger proportionately in *Congiopodus* than in *Trigla*—a related fish the sounds of which are restricted to the breeding season—and in the absence of information about the role of fish sounds in orientation and communication it is worth speculating that the cerebellum is being used in the integration of the drumming response possibly in relation to reception of its own sounds or those of other members of the school.

This work was done while at the Portobello Marine Biological Station, supported by the Nuffield Foundation. I am indebted to Dr. G. H. Satchell for assistance with the recording, which was carried out in the Department of Physiology, University of Otago Medical School, New Zealand.

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Immunoelectrophoretic Studies on Purified Human Growth Hormone

The antigenicity of purified preparations of human growth hormone have been demonstrated by means of a modified tanned cell hæmagglutination method[1], precipitin ring tests[1,2], gel-diffusion studies[2,3] and by immunoelectrophoresis[4].

In immunoelectrophoresis the growth hormone appears as a β-globulin and evidence has been presented for its purity by this technique[4].

In the following experiment, five rabbits (*A–E*) were immunized with 2 mgm. human growth hormone purified according to the technique of Li and Papkoff[5] and mixed with Freund's adjuvant[6]. The injections were given once a week for three weeks, each rabbit obtaining 2 mgm. subcutaneously each time, and one month later 1 mgm. of growth hormone without adjuvant intravenously. One week later the animals were bled and the sera tested in hæmagglutination experiments and immunoelectrophoresis. The hæmagglutination titres of these sera were 1 : 30,000–1 : 80,000.

The immune sera were tested in immunoelectrophoresis against the purified growth hormone preparation in a concentration of 1 mgm./ml. and against undiluted human serum from an evidently normal blood donor.

All immune sera gave a single precipitate in the slow α-globulin region against the growth hormone preparation. This precipitate presented an extended slightly asymmetric shape against four of the immune sera, and when immune serum *D* was used to develop the pattern a two-peaked symmetrical precipitate was obtained (Fig. 1).

The shape of the precipitate is among other factors depending on the relative distribution of serologically identical molecule populations in the electrophoretic field, and a two-peaked symmetrical precipitate is obtained if two electrophoretically different although serologically identical molecule populations are mixed in the same amounts and subjected to immunoelectrophoresis provided the difference in electrophoretic position between those molecule populations is not too pronounced[7].

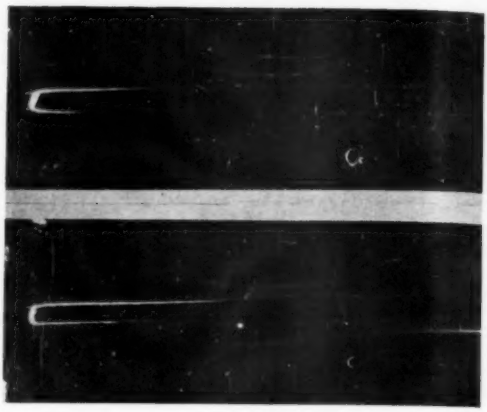

Fig. 1. Immunoelectrophoretic pattern of purified growth hormone (upper basin) and a normal serum (lower basin) as revealed by anti-growth hormone immune serum *C* (upper plate) and *D* (lower plate). To the far left the albumin precipitate is seen in the lower basins

Against one of the immune sera (immune serum *B*) a further precipitate was obtained in the fast α-globulin region.

In conclusion the purified growth hormone preparation appeared immunologically homogeneous when tested against four immune sera prepared on different rabbits. The fifth immune serum (*B*) revealed evidence of another serologically and electrophoretically different component. The single precipitate presumed to represent the growth hormone precipitate was found to be asymmetrical or two-peaked, indicating that it consists of two electrophoretically different although serologically identical molecule populations.

All immune sera against the purified growth hormone preparation also reacted with albumin and γ-globulin in an evidently normal serum. Some of the immune sera also reacted with other components as, for example, the α_1-glykoprotein (*TBP*)[8] and 1–2 α_2-globulins. The γ-globulin precipitate in all instances appeared more extended than when developed with a homologous immune serum.

In the normal serum, no precipitate was found which agreed with the presumed growth hormone precipitate as regards electrophoretic position, site between diffusion centres or shape of the precipitate.

An anti-human immune serum did not give any precipitate formation against the growth hormone preparation, although giving at least 18 different precipitates with a normal human serum (Fig. 2). It might therefore be suspected that impurities mainly of albumin and γ-globulin are present in the purified growth hormone preparation in amounts

Fig. 2. Immunoelectrophoretic pattern of same material as in Fig. 1 developed with an antihuman immune serum. (Upper basin: purified growth hormone 1 mgm./ml.; lower basin, a normal serum.) No precipitates are seen in the upper basin

sufficient to elicit antibody formation although not sufficient to give precipitate formation in the present experimental circumstances. As another possibility, the antibodies against the growth hormone itself might be suspected of also reacting with certain normal serum constituents. Absorption of one immune serum against the growth hormone preparation with a normal human serum by means of intra-basin gel-absorption[9] did not, however, absorb the antibodies against the growth hormone preparation.

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Increase of Esterase Activity during Intracellular Digestion in a Histophagous Ciliate

THE macrophages of vertebrates and invertebrates[1] as well as some Protozoa[2] exhibit strong esterase and lipase activity demonstrable by histochemical and biochemical methods. Considering the prominent position of the hydrolytic enzymes in digestive processes, it seems probable that they have also some significance in the intracellular breakdown of particles, a common characteristic of both cell-types in question. In the course of our recent work on the problems of feeding and digestion in a histophagous ciliate, *Tetrahymena corlissi* Thompson, strain *W*, we obtained some results that may confirm this assumption.

Cells of *T. corlissi*, grown axenically on a tryptone (1 per cent) and yeast extract (0·05 per cent) broth, were washed twice in Prescott solution and kept during the experiments in the same solution. Fresh frozen sections of rat spleen served as food. The animals readily ingested the spleen cells. Smears of unfed and fed (for 1 hr.) animals, and those of animals starved (2–24 hr.) in Prescott solution after feeding, were fixed in cold 10 per cent formalin (1 hr.). The 'Tween' procedure of Gomori[3] and the azo-dye procedure of Nachlas and Seligman[4] were used for the demonstration of esterases. The slides were mounted in glycerine-jelly.

Unfed animals exhibited a slight or moderate activity on the substrates α-naphthyl acetate, 'Tween 60' and '80'. Parallel with the formation of food vacuoles a great increase in esterase activity has been observed. Using α-naphthyl acetate, which gives a distinctly localized reaction product, the food vacuoles could be demonstrated as the site of the increased activity (Fig. 1). The 'Tween' procedure revealed only a general increase in the activity, but did not show its intracellular localization. In animals

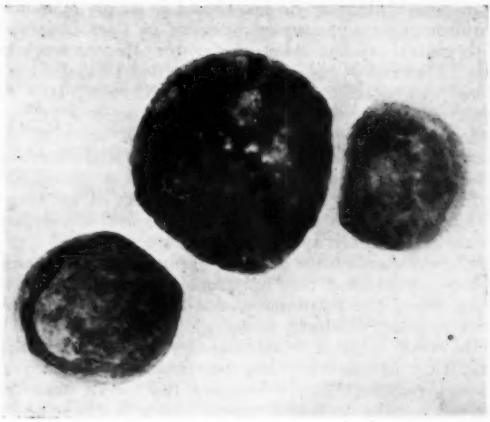

Fig. 1. One fed and two unfed cells of *T. corlissi*. The food vacuoles of the fed individual exhibit a strong esterase activity. Azo-dye method

starved after feeding there is a drop in the activity to the initial level within 24 hr. The digestion is already completed at this time and the animals contain only empty vacuoles as revealed by the control slides stained with hæmatoxylin.

These changes are probably due to an activation of the enzymes and may indicate an intimate correlation of the esterases with the intracellular digestion. Our recent findings do not enable us to determine the type of the enzymes responsible for the increase observed. The splitting of both substrates, α-naphthyl acetate and the unsaturated 'Tween 80', seems to indicate that at least a non-specific esterase and a lipase may be at work. Further studies aiming at a more detailed characterization of the enzymes are in progress.

We wish to thank Dr. J. O. Corliss for the strain of *T. corlissi* and the Difco Co., Ltd., for supplying us with a sample of tryptone and yeast extract.

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A High-Energy Phosphate Requirement for Succinate Oxidation in Uncoupled Rat Liver Mitochondria

IT has been reported by Borst and Slater[1,2] that rat liver mitochondria, depleted of endogenous phosphate by pre-incubation with hexokinase and glucose, showed a marked phosphate requirement for the oxidation of glutamate in the presence of 2,4-dinitrophenol. This phosphate requirement was attributed to the substrate-level phosphorylation linked to the oxidation of α-ketoglutarate which is not uncoupled by dinitrophenol. Evidence has been given that other Krebs-cycle metabolites, such as succinate,

citrate, and malate, did not show the same phosphate requirement in uncoupled systems as that observed with glutamate and α-ketoglutarate. Recent work in this Laboratory[2] has shown that when mitochondria were pretreated for 2 min. at 30° C. with 10^{-4} *M* dinitrophenol or with 10^{-4} *M* dinitrophenol + 10^{-3} *M* adenosine-5′-phosphate, in both cases in 0·25 *M* sucrose, and afterwards washed twice with sucrose, other Krebs-cycle metabolites showed a phosphate requirement very similar to that observed by Borst and Slater in the case of glutamate and α-ketoglutarate. In such systems succinate was the only Krebs-cycle substrate the aerobic oxidation of which proceeded without any apparent phosphate requirement when the respiration was measured using the conventional Warburg technique.

However, a more detailed analysis of the succinate oxidation in mitochondria pretreated with dinitrophenol, performed by measuring the initial phase of oxygen uptake with the oxygen electrode, has shown that the requirement for phosphate in this system is even more striking than that observed with other Krebs-cycle metabolites. Moreover, succinate not only required inorganic phosphate for maximum oxidation but also the inorganic phosphate had to be added to the mitochondria together with the succinate, prior to the addition of the uncoupler, since inorganic phosphate added after the addition of dinitrophenol or of dicoumarol was no longer able to

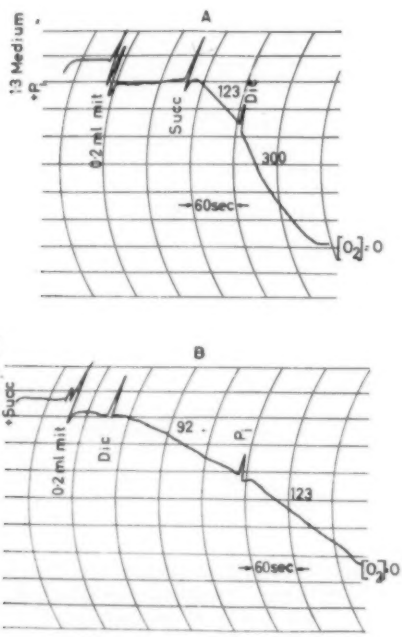

Fig. 1. Inorganic phosphate requirement for oxidation of succinate in 2,4-dinitrophenol-pretreated rat liver mitochondria. The inorganic phosphate is able to stimulate respiration only if added before the uncoupler (*A*), and not if added after the uncoupler (*B*). Concentrations of the reagents in a final volume of 1·5 ml. were as follows: 0·05 *M* potassium chloride, 0·033 *M* *tris* buffer, pH 7·5, 0·008 *M* magnesium chloride, 0·05 *M* sucrose, 0·013 *M* succinate (*Succ*), 0·003 *M* inorganic phosphate (*Pi*), 0·00006 *M* dicoumarol (*Dic*). Mitochondria from 400 mgm. rat liver wet weight (about 8 mgm. protein). The substances were added at the points indicated. '1·3 Medium' stands for potassium chloride, *tris* and magnesium chloride, added in a volume of 1·3 ml. Oxidation-rate of succinate is given in mμ atoms oxygen per min.

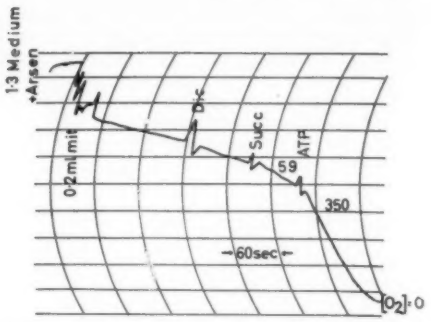

Fig. 2. Stimulation of succinate oxidation by adenosine triphosphate in an arsenate–dicoumarol-inhibited system. Concentrations of reagents were as given in Fig. 1. 0·002 *M* arsenate (*Arsen*) and 0·0013 *M* adenosine triphosphate (*ATP*) were added at the points indicated. Oxidation-rate of succinate is given in mμ atoms oxygen per min.

stimulate succinate oxidation. Evidence for this effect is demonstrated in Fig. 1 by showing the different rates of succinate oxidation in mitochondria pretreated with dinitrophenol according to the different order of addition of succinate, inorganic phosphate and dicoumarol. The above effect suggested that the presence of both inorganic phosphate and succinate, prior to the addition of the uncoupler, was needed for synthesizing high-energy phosphate. It therefore seemed that the dinitrophenol pretreatment had brought the mitochondria into a condition where high-energy phosphate was required for oxidizing succinate at maximum rate.

The validity of this hypothesis was tested with rat liver mitochondria depleted of phosphate by pre-incubation in the presence of arsenate and dicoumarol, since it has been observed[3] that incubation with arsenate is the most efficient means tried to deplete the mitochondria of both inorganic and high-energy endogenous phosphate. As shown in Fig. 2, the addition of succinate to normal rat liver mitochondria pre-incubated for 3 min. in the presence of 2 m*M* arsenate and 6×10^{-5} *M* dicoumarol resulted in a very low respiration. The addition of 1 m*M* adenosine triphosphate to this inhibited system was able to stimulate the respiration 4–6-fold, bringing the oxidation rate of succinate to about 50–60 per cent of the level obtainable by the addition of dicoumarol to rat liver mitochondria in the presence of succinate.

The possible interference of oxaloacetate as inhibitor of the succinate oxidation in our system, although very improbable because of the fact that succinate was added last to the arsenate–dicoumarol-inhibited system, was ruled out by the addition of cysteine-sulphinic acid, which was not able to stimulate the inhibited respiration although it was able to remove oxaloacetate by way of a transaminase reaction[4]. Moreover, the oxidation of succinate with phenazine metosulphate as electron acceptor was not inhibited in this system.

Another aspect of the inhibition of the succinate oxidation, described above, was obtained by testing the effect of amytal. As shown in Fig. 3, addition of 2 m*M* amytal to mitochondria prior to, or simultaneously with, the addition of arsenate and dicoumarol resulted in a complete prevention of the respiratory inhibition. This effect of amytal was probably due to bringing the mitochondrial diphosphopyridine nucleotide into the reduced state (by way of endogenous mitochondrial substrates)

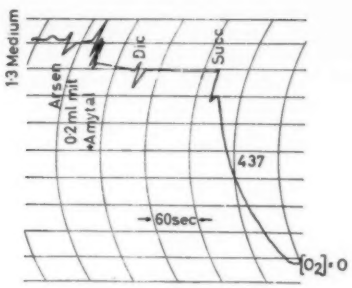

Fig. 3. Protection by amytal of succinate oxidation in an arsenate–dicoumarol-inhibited system. Concentrations of reagents as given in Figs. 1 and 2. 0·002 *M* amytal was added, together with the mitochondria at the point indicated. Oxidation-rate of succinate given in mμ atoms oxygen per min.

since it failed to occur when the amytal was added after the arsenate and dicoumarol, or when it was tested in mitochondria pretreated with dinitrophenol plus adenosine-5′-phosphate; addition of glutamate and inorganic phosphate to the latter system restored the amytal effect.

The results presented here strongly indicate that the oxidation of succinate in phosphate-depleted, uncoupled mitochondria is influenced by the redox status of one or more carriers in the amytal-sensitive region of the respiratory chain. The conditions required for succinate oxidation may be fulfilled either by an extensive reduction of the mitochondrial diphosphopyridine nucleotide or by the addition of high-energy phosphate, the latter possibly acting by a 'reversal of the oxidative phosphorylation'. This hypothesis is in line with the observations reported from different laboratories[5,6] that the oxidation of succinate in intact mitochondria is accompanied by a high degree of reduction of diphosphopyridine nucleotide, even higher than that observed with substrates linked with diphosphopyridine nucleotide. The interest of the present findings may lie in the fact that adenosine triphosphate apparently can influence the respiratory chain in spite of the presence of phosphorylation-uncouplers, or in other words, that dinitrophenol (and other uncouplers) apparently only inhibit the forward, but not the backward, reaction of respiratory chain phosphorylation. This concept is in agreement with the postulated mechanisms of phosphate–adenosine triphosphate exchange and dinitrophenol-induced adenosine triphosphatase reactions previously formulated at this Institute[7].

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Total and *l*(+) Tartaric Acid Inhibited Rat Serum Acid Phosphatase

THE activity of the total acid phosphatase has been determined in many of the rat's tissues, but data on the activity of this enzyme in rat serum are scant[1,2]. We did not find any report dealing with *l*(+) tartaric acid inhibited acid phosphatase in rat serum.

The purpose of the present investigation was to determine the activities of the total and *l*(+) tartaric acid inhibited acid phosphatase in the serum of rats of both sexes. The results of our work are shown in Table 1. It is evident that the activity of both serum total and *l*(+) tartaric acid inhibited acid phosphatase is much higher in the rat than in the human serum in which the mean activity is 2·5 King–Armstrong units in adults and 5 King–Armstrong units in children[3]. Although the mean activity of the serum total acid phosphatase in small rats is slightly higher than the mean activity in bigger rats of the same sex, and the mean activity in big male rats higher than in big female rats, the differences are statistically not significant.

Table 1. SERUM TOTAL AND 1(+) TARTARIC ACID INHIBITED ACID PHOSPHATASE IN RATS

Group No.	Sex	Weight (gm.)	No. of rats	Serum total acid phosphatase in King–Armstrong units; mean ± *S.D.*	Serum *l*(+) tartaric acid inhibited acid phosphatase in King–Armstrong units; mean ± *S.D.*
I	Male	40–50	12	18·5 ± 2·98	6·79 ± 2·3
II	Male	140–180	19	17·3 ± 4·92	8·68 ± 3·4
III	Female	40–50	8	17·3 ± 2·1	7·3 ± 2·93
IV	Female	120–160	10	14·9 ± 3·17	6·7 ± 1·26

White rats were anæsthetized with 'Nembutal'. Blood was drawn from the abdominal aorta, twice centrifuged and the enzyme activities determined immediately thereafter according to the methods of King (ref. 5) and Fishman (ref. 6).

The proportion of the *l*(+) tartaric acid inhibited to the non-inhibited serum acid phosphatase ranges from 1 : 2 to 1 : 1, a higher proportion than that found in humans. The mean activity of the *l*(+) tartaric acid inhibited phosphatase in the serum of big male rats is higher than in the serum of female rats of the same age and weight-range ($P < 0{\cdot}05$; *t* test). This may be due to prostatic activity.

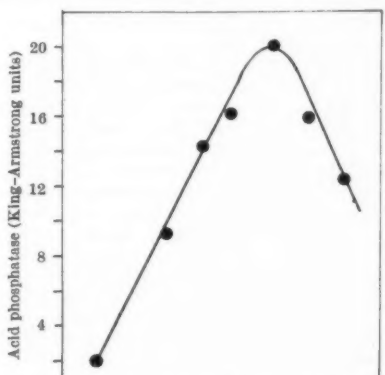

Fig. 1. *p*H enzyme activity curve for total serum acid phosphatase (citrate buffer)

The *p*H optimum of total acid phosphatase was found to be *p*H 5·5 (Fig. 1). Dialysis against citrate buffer *p*H 4·9 at 4° C. for 24 hr. did not change the activity.

It is not clear which tissues contribute to the high activity of the total and *l*(+) tartaric acid inhibited acid phosphatase in the rat serum. The optimum *p*H of 5·5 points to the red cells as a possible source of the uninhibited acid phosphatase[4]. (The *p*H optimum of the inhibited enzyme could not be detected over the range of *p*H 3–6.) The high activity of the *l*(+) tartaric acid inhibited enzyme in female rats shows that there exist major sources for it other than the prostate.

From this work it seems that younger rats do not have statistically higher serum acid phosphatase activity than older ones such as in humans[3], but without serial determinations at many ages starting in very young animals this question cannot be definitely answered.

Rat serum with a high activity of total and *l*(+) tartaric acid inhibited acid phosphatase presents a valuable tool for the study of the properties of the above enzyme.

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Physiological Media for Tissues of *Helix*

During the course of recent work in this School, it became necessary to find a physiological saline suitable for the tissues of *Helix aspersa* Müller. The saline was required for a series of experiments on oxygen-uptake by certain tissues of *Helix*, using the Warburg method.

Two solutions suggested themselves for consideration: that of Bernard and Bonnet[1] and that of Hédon–Fleig[2]. The former solution contains the chlorides of sodium, potassium, calcium and magnesium; no buffer is required and no sugar is provided. It was devised for experiments on the heart of *Helix pomatia*, and is capable of supporting heart-beat for periods of up to four days. A factor in favour of this solution is the ease with which it can be prepared. The Hédon–Fleig solution is more complex: it contains a phosphate buffer, is provided with a sugar, and requires adjustment to a *p*H of 8·4. Moreover, it requires special measures for sterilization, since the use of heat causes liberation of carbon dioxide and a consequent rise in alkalinity.

The Bernard and Bonnet solution was used in the first of the series of experiments referred to above. The tissues investigated were: (*a*) slices of liver and ovotestis (no effort made to separate the two tissues) —two flasks; (*b*) slices of the common duct of the reproductive tract—two flasks. All the flasks registered a rapid and progressive decline in oxygen-uptake commencing within 30 min. of the start of the experiment (that is, from the first manometer reading) (Fig. 1). In all cases oxygen consumption ceased within 1 hr.

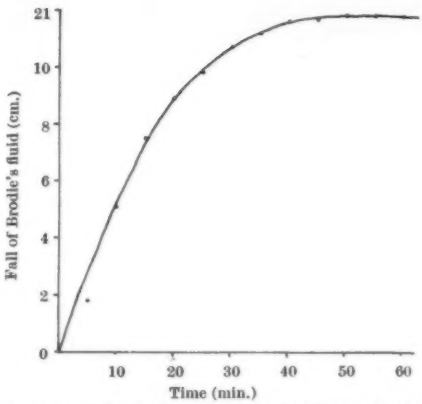

Fig. 1. Oxygen uptake, measured as a fall of the Brodie's fluid in the manometer, plotted against time. Slices of liver and ovotestis in Bernard and Bonnet saline

In the second and subsequent experiments Hédon-Fleig saline was used. Tissue slices were taken from: (*a*) liver and ovotestis; (*b*) common duct; (*c*) albumen gland; (*d*) penis; (*e*) gonad (no liver tissue attached); (*f*) crop with salivary glands attached. Several 'runs' were performed with tissues (*a*), (*b*) and (*c*). In contrast with the earlier results, the rates of oxygen-uptake usually remained constant throughout the experiments, which lasted from 1¼ to 1¾ hr. (Fig. 2). This observation indicates that the saline was not at fault in the few cases where the rate of oxygen uptake tended to decline. Moreover, when a decline occurred it was invariably small, and in no case did oxygen-consumption cease within the period of the experiment.

Although the first experiment (Bernard and Bonnet saline) was not repeated, the results are regarded as reliable. It is concluded that, whatever the merits of the Bernard and Bonnet saline where the snail heart is concerned, for most tissues of *Helix*

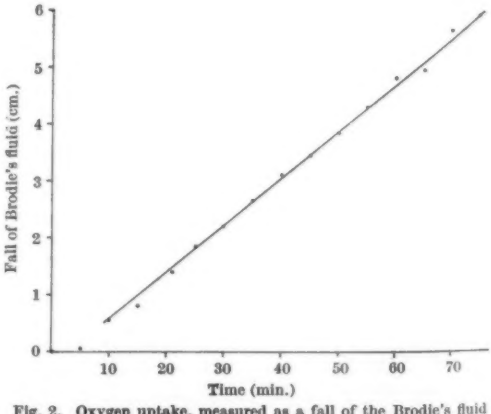

Fig. 2. Oxygen uptake, measured as a fall of the Brodie's fluid in the manometer, plotted against time. Slices of liver and ovotestis in Hédon–Fleig saline

the Hédon–Fleig solution is a more suitable physiological medium.

It is of interest to note that Prosser[3] gives a formula for a physiological solution for *Helix* and attributes the formula to Bernard and Bonnet[1]. However, the formula given by Prosser bears no resemblance to that of Bernard and Bonnet. Moreover, it yields a considerable amount of precipitate which persists at all temperatures from about 20° C. to boiling point. Prosser's formula was therefore regarded as an error and was not used in these experiments.

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'Water Rigour' as an Aid when Operating on Marine Gastropoda

WHILE investigating the physiological aspects of the distribution of two species of the marine gastropod *Bullia*, one of us (A. C. B.) discovered that these snails can crawl only between certain limits of salinity. As the salinity of the sea-water is decreased by the addition of distilled water, movements become more and more restricted, eventually resulting in the total loss of locomotory powers while the animal becomes distended due to the osmotic inflow of water. Providing that dilution is accomplished reasonably slowly (taking 60 min. or more) the foot is not retracted at any stage, while the excitability of the muscles is greatly reduced or disappears completely. The animal remains motionless with stiff, swollen tissues. For *Bullia digitalis* Meuschen, this critical salinity lies in the region of 1·8 per cent, while in the case of *B. laevissima* (Gmelin) it is about 2·35 per cent. Loss of locomotory powers due to decreased salinity has previously been noted for some rocky-shore gastropods by Broekhuysen[1] and Brown[2]. The phenomenon resembles the loss of contractility in vertebrate skeletal muscle subjected to 'water rigour'. However, in *Bullia* the process is completely reversible. The snails can be kept for some hours at these reduced salinities without apparent ill-effect; when returned to fresh, undiluted sea-water they soon recover and behave normally.

A fuller account of this work is soon to be published.

It is well known that most operations for experimental purposes on Gastropoda are extremely difficult, because of the powerful contractions of the animal's muscles. Anæsthetics, to which the snails are rather insensitive, do not prevent contractions satisfactorily, even if the animals are so heavily drugged that they do not recover. In connexion with research on the function of the osphradium in *Bullia*, we were interested in severing the osphradial nerve of the living snail. At first we were at a loss for a successful method of performing such a delicate operation, but then it occurred to us that animals subjected to 'water rigour' might prove to be suitable subjects. A number of snails were therefore brought into this condition. As expected, the snails could then be operated on without any difficulties arising from muscular contractions. A window was cut in the shell, over the osphradium and dorsal pallial artery, and the osphradial nerve was then severed with a small eye-surgeon's scalpel. When returned to undiluted sea-water, more than half the snails operated on recovered and were used for experiments on sensory perception. None of these showed any abnormal behaviour which could be attributed to previous 'water rigour'.

Those snails which did not recover were later dissected in order to discover the cause of death. In all of them it was found that structures other than the osphradial nerve had been injured during the operation; in most cases the pallium had been damaged. In no snail was there any evidence that the reduced salinity conditions to which they had been subjected had produced ill-effects.

Other work in our Department (unpublished experiments by G. Noble) has confirmed that 'water rigour' is a very effective aid when operating on *Bullia*, not only for the operation described above but also in removal or cauterization of organs possibly connected with sensory perception, such as the inhalant siphon, tentacles, etc. It seems likely that the 'water rigour' technique might find wider application in the field of gastropod physiology.

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IMMUNOLOGY

Natural Occurrence of Delayed-type Iso-hypersensitiveness

EVIDENCE has been obtained for the existence, in certain normal guinea pigs, of a state of delayed iso-hypersensitiveness to a heritable factor present in the serum of other normal guinea pigs. This condition, which arises at about 2 months of age, appears analogous to the long known[1] natural existence of circulating iso-antibodies to heritable blood group antigens in other species. Delayed-type hypersensitivity to isophile antigens may, of course, be experimentally induced (*cf.* ref. 2), but its spontaneous occurrence seems not to have been suspected.

The occurrence of delayed skin reactions among guinea pigs inoculated for the first time with the sera of others is illustrated by a typical experiment. The sera of 12 adult albino guinea pigs (bred from Rockefeller Institute stock) were injected separately into the skin of the back of each of the animals; thus, every animal received 0·1 ml. of 1 : 3 dilution in saline of its own as well as of the 11 other sera. As shown in Table 1, certain of the guinea pigs (Nos. 1–3) responded to the sera of most of the other animals, though not to their own, with erythematous skin

Table 1. DELAYED SKIN REACTIONS GIVEN BY CERTAIN NORMAL GUINEA PIGS TO THE SERA OF OTHER NORMAL GUINEA PIGS

Test of serum from guinea pig No.:	Reaction of guinea pig No.: 1	2	3	4	5–12
1, 2, 3	0	0	0	0	0
4	±	0	0	0	0
5, 6, 7	+	+	+	0	0
8, 9	+	+	±	0	0
10	+	±	+	0	0
11, 12	+	±	±	0	0

0, ±, + = erythema 0–4, 5–9, 10–14 mm. in diameter, at 18–24 hr.

Table 2. Inheritance of the Serum Factor(s) in Guinea Pigs eliciting Delayed Skin Reactions in Other Normal Guinea Pigs

No. of pairs	Parental pairs: Serum factor* ♀	× ♂	Live offspring: Serum factor* +	−	Fœtal death-rate†
15	+	+	79	1	0·9
8	+	−	14	19	2·1
8	−	+	23	18	2·4
12	−	−	0	85	2·8

* Determined by skin tests in which 0·1 ml. of undiluted serum, from animals at least 2 months old, was injected intradermally into each of 2–4 animals known to be dermally reactive. Sera were judged positive if they evoked reactions of at least 10 mm. in diameter.

† Stillborn and neonatal deaths per 10 live births.

reactions that first were noticeable in 8–10 hr., were maximal at 18–24 hr., and lasted several days. The remaining 9 animals showed insignificant reactions; instead, each (except No. 4) possessed serum capable of evoking a definite response in one or more of the first group.

Comparable experiments, in which guinea pigs of Rockland Farms stock were tested with each others' undiluted sera, likewise differentiated (*a*) dermally reactive animals the sera of which did not evoke skin reactions, (*b*) dermally non-reactive animals possessing sera capable of evoking reactions in others, and (*c*) individuals with neither positive attribute. On the other hand, no dermal reactor was found in a limited test (18 animals) of a third guinea pig stock.

What is doubtless the generalized counterpart of the local skin reaction has been observed in non-immunized animals corresponding to Nos. 1–3 of Table 1. Such animals displayed delayed erythema of the skin of the entire body following intravenous inoculation of 3–4 ml. of a pooled serum which had, one day earlier, elicited local delayed skin reactions in them. The characteristics of these local and general reactions clearly set them apart from the immediate-type cutaneous reactions, related to permeability substances[2], seen in virtually all guinea pigs inoculated with unselected homologous sera.

The factor in serum that evokes the delayed skin response is inactivated by boiling, but not by heating the serum at 56° C. for 30 min. It migrates electrophoretically with the β-globulins[4]. When present, serum factor is detectable from birth and appears to increase as the animal matures. That it is inherited is evident from mating experiments (Table 2). Thus, when present in both parents, serum factor (*SF*) appeared in 79 of 80 live offspring; when present in one parent, about half the offspring possessed it; and when absent in both parents, it was not detected in the young (85 live animals examined). In matings in which the male possessed and the female lacked serum factor and, hence, could not transmit it preformed to her young, serum factor was found in 23 of 41 offspring. The inheritance mechanism is under investigation, as is the question of whether parental (possibly maternal) lack of serum factor is associated with increased fœtal mortality, as suggested by the data in Table 2.

The delayed reactivity of certain guinea pigs to the serum of others is not in response to an inherently toxic substance, as originally believed[5], but rests on an immunological basis. Passive transfer of the reactive capacity has been achieved by transplanting lymphoid cells from dermally reactive animals to adult recipients pretreated by neonatal injection of small numbers of donor leucocytes[6], or by total-body X-irradiation. For reasons not yet clear, efforts to transfer dermal reactivity to normal animals have failed.

Table 3 illustrates the results of a set of transfer experiments in which individual donors were either dermally reactive (exp. *A–D*) or non-reactive (*E*, *F*). To assess the reactivity of donor and recipient animals a single pool of 3 individual guinea pig sera positive for serum factor was used, with a pool of 3 sera lacking serum factor as control. Preparations prior to each transfer were as follows. After determining the dermal reactivity of the donor animal, washed leucocytes from 2 ml. of its blood were injected intravenously into each of several guinea pigs (less than 24 hr. old) born of parents lacking both serum factor and dermal reactivity. (About 75 per cent of such offspring would also lack both attributes.) When about two months of age, the presumed chimeras of each particular donor were skin-tested, along with the donor. On the following day, one of the young—provided it was found to lack dermal reactivity to serum factor—was injected with the donor's washed spleen and lymph node cells (the equivalent of 0·15 ml. and 0·10 ml. packed cells) intraperitoneally as well as intravenously. When available, a second recipient was given the donor's serum (2–3 ml. daily for 3 days) by the same routes. Tests for dermal reactivity were made on the third day following transfer and on two or three further occasions during the intervals shown in Table 3.

Dermal reactivity was conferred upon normally non-reactive animals by the lymphoid cells of reactive donors (exp. *A–D*) in a time sequence typical of passive transfer of delayed-type hypersensitivity[7,8]. The transferred reactivity appears specific for serum factor as no recipient reacted significantly to the pool of sera lacking serum factor. In control experiments *E–F*, lymphoid cells from two non-reactive donors failed to confer reactivity upon comparably pretreated recipients.

Table 3. Cellular Transfer of Delayed Skin Reactivity from Naturally Reactive to Non-reactive Guinea Pigs (Preconditioned by Donor Leucocytes)

Animal skin tested	Time of skin test, pre- or post-transfer	Reactions to sera containing or lacking serum factor*											
		A		*B*		*C*		*D*		*E*		*F*	
		SF+	*SF*−	*SF*+	*SF*−	*SF*+	*SF*−	*SF*+	*SF*−	*SF*+	*SF*−	*SF*+	*SF*−
Donor of cells, serum	1 day pre-	++	0	++	±	+±	0	++	±	0	0	±	±
Recipient of lymph node and spleen cells	1 day pre-	0	0	±	0	0	0	0	0	0	0	0	0
	3 days post-	++	0	±	0	0	0	0	0	±	±	0	0
	6–8 days post-			+±	±	+	0	±	0	0	0	±	±
	10–12 days post-	++	±	+±	0	+	±	+±	±			±	±
	18–22 days post-	±	±	±	±	±	±	++	0	0	0	±	±
Recipient of serum	1 day pre-	0	0					0	0	0	0		
	3–22 days post-	0	0					±	±	0	0		

* Reactions to intradermal inoculations of 0·1 ml. of undiluted pooled sera containing serum factor (*SF*+) or lacking it (*SF*−). 0, ±, +, +±, ++ = erythema 0–4, 5–9, 10–14, 15–19, 20–24 mm. in diameter at 18–24 hr.

The grouping of guinea pigs on the basis of presence or absence of heritable serum factor appears fundamentally similar to the differentiations made within other species based on the occurrence of heritable substances in the sera of some but not all individuals. That is, guinea pig serum factor may be likened to the haptoglobins, transferrins, ceruloplasmins, etc., visualized by starch-gel electrophoresis in the sera of cattle and man[9], or to the gamma-globulin allotypes of rabbits[10]. Indeed, serum factor appears most closely analogous to the Lewis antigens of man[11] and the *J* substance of cattle[12], since natural iso-antibodies (though of circulating type) occur against these substances. Work is in progress to determine whether guinea pig serum factor may be associated with circulating iso-antibodies, may be visualized electrophoretically, or has a discernible biological function. The existence in the guinea pig of what is evidently a new type of 'iso-immune' state, namely, delayed iso-hypersensitivity, suggests the possibility that a similar state may occur in other species, especially those cited above, and may have escaped detection perhaps because of low frequency.

I am grateful to Dr. Edward J. Hehre for guidance, for help with this manuscript, and for the term 'iso-hypersensitivity'. Thanks also are due Miss Janet F. Parks and Miss Rita Hixon for technical assistance.

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PATHOLOGY

Bone Marrow Depression in Murine Leukæmia

ON occasions the appearance of leukæmia in humans is preceded by a period of bone marrow depression and evidence of aplastic anæmia[1]. Such findings may persist for some time and may result in confusion in diagnosis or the leukæmia is regarded as an aleukæmic form of the disease. In a group of *A* strain mice at present being studied for the effects of intermittent X-radiation, it was noted that while, as expected, the mice developed lymphocytic neoplasms and leukæmia in response to the irradiation, a significant proportion of animals with these diseases also showed aplastic or hypoplastic changes in their marrows when examined at autopsy. This hypoplasia initially affected the erythropoietic cells (Fig. 1), but as it became more severe appeared to affect all

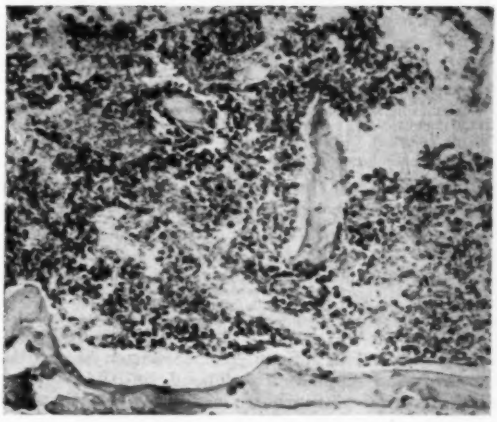

Fig. 1. Hypoplastic bone marrow from vertebra. Diminution mainly in erythropoietic cells. Female mouse with non-thymic lymphoid leukæmia. Received 1,000 r. total body intermittent X-radiation. Age, 385 days at death. Hæmatoxylin and eosin. (× 200)

elements of the bone marrow (Fig. 2). The incidence of lymphoid leukæmia and the various forms of that disease in this group of mice have been considered elsewhere[2]; this communication presents some of the features of the marrow depression which is seen in the mice with lymphoma and lymphoid leukæmia. Table 1 shows the distribution of marrow hypoplasia or aplasia in the different groups of mice. A fuller discussion of the incidence of this condition, its time of appearance and relationship to radiation dose will be presented elsewhere. However, it is obvious that two factors, apart from radiation, appear to increase the incidence of bone marrow depression; they are femaleness and the absence of a thymic tumour or enlargement.

It is known that a number of endocrine secretions, for example, adrenal steroids, sex hormones, may influence lymphoid tumour production in the mouse and, in general, hormones which appear to diminish the size of the thymus appear to inhibit the genesis of

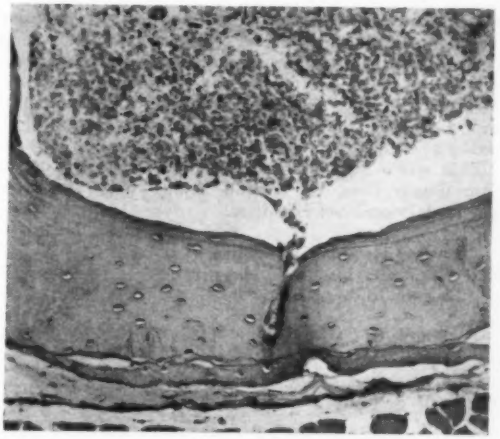

Fig. 2. Aplastic bone marrow—right mid-femur. Female mouse with non-thymic lymphoid leukæmia. Received 1,000 r. total body intermittent X-radiation. Age, 318 days at death. Hæmatoxylin and eosin. (× 200)

Table 1

a Total numbers of experimental mice

	Radiated mice		Control mice	
	Male	Female	Male	Female
With leukæmia	108	121	20	17
Without leukæmia	495	455	89	102

b Animals with bone marrow depression in relation to total numbers

With leukæmia	24 (22·2%)	44 (36·3%)	1 (5·0%)	2 (11·7%)
Without leukæmia	59 (11·9%)	60 (13·1%)	2 (2·2%)	6 (5·8%)

c Total numbers of animals with different forms of leukæmia

Thymic	73	62	2	2
Non-thymic	35	59	18	15

d Animals with bone marrow depression in relation to different forms of leukæmia

Thymic	7 (9·5%)	16 (25·8%)	0 (0%)	1 (50%)
Non-thymic	17 (48·5%)	28 (47·5%)	1 (5·5%)	2 (15·5%)

Leukæmia here signifies a generalized neoplastic disease, with or without thymic enlargement, in which the tumour cells are almost all immature lymphocytes. Radiation was given as 100 r. weekly total body X-radiation to totals of 500 r., 1,000 r. and 1,500 r.

lymphoma[3]. The influence of œstrogen is a little obscure, and appears to depend on the time of administration of the hormone in relation to radiation[4]. Recently, Metcalf[5] has claimed that the thymus secretes a hormone-like substance, lymphocytosis-stimulating factor, the levels of which are raised in mice with a high incidence of spontaneous leukæmia and in mice following radiation. Throughout the life of mice unaffected by infectious disease, the commonest circulating leucocyte is the lymphocyte, and it must be assumed that such cells probably bear the brunt of the immunological defences in that species. Consequently, interference with the mechanisms of control of lymphocyte production and function probably have serious consequences for the mouse. We know that œstrogens may cause marrow aplasia in dogs and in spayed rats—abnormalities which may be corrected by testosterone[6]. We also know that testosterone may produce a rise in red-cell numbers in women who have carcinoma of the breast and who are treated with this hormone[7], and recently testosterone has been used in the treatment of aplastic anæmia in children with success[8].

The present findings indicate further the complexity of the pathogenesis of lymphoid leukæmia in the mouse. At least two hormone systems, the sex hormones and, if it can be shown to be a distinct hormone, lymphocytosis-stimulating factor, appear to be directly implicated. While it is not permissible to transfer directly findings in the mouse to humans, it would seem reasonable to try testosterone administration in those patients with aplastic crises in leukæmia and also in those patients who present with aplastic or hypoplastic bone marrow pictures. Some of these latter may ultimately develop frank leukæmia, and attempts at marrow regeneration may allow earlier recognition of the disease.

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VIROLOGY

Isolation of a Non-pathogenic Tumour-destroying Virus from Mouse Ascites

Anomalies of growth of an ascites tumour, consisting of aggregation of tumour cells and other changes, first reported in 1957 [1], led to the belief that the tumour was reverting to a solid habit of growth, and selective transplantation was undertaken with the object of segregating solid and fluid variants. As this investigation proceeded, the aggregation effect showed signs of evolving into a more advanced pathological state, with increasing indications of destruction of tumour cells. Many sublines were lost as the incidence of no-takes after massive counted implants increased. Many such no-take animals survived for long periods with no signs of illness or delayed tumour development.

Evidence was obtained that the phenomenon is due to an antigenic tumour-destroying agent, and after excluding a bacterial causation, a virus-like agent was looked for. Vaccinia was thought to be implicated but this was not confirmed, though it seems likely that it was in some way associated with the development of destructive effect on tumours[2].

Early attempts to transmit infectivity by means of filtrates were unsuccessful, probably on account of high losses on filtration; but samples from one 'abnormal tumour' subline which had been stored at −50° C. provided a bacteriologically sterile filtrate that had a potent destructive effect on the Krebs 2 ascites and the Ehrlich ascites tumours obtained from the Chester Beatty Institute and maintained in isolation. Preliminary results show that the sarcoma 37, the Landschutz, the *BP*/8, and the Crocker ascites tumours are also destroyed.

That the agent multiplies is shown by its recovery after serial transmission five times in sterile filtrates obtained from washed Ehrlich cells after infection *in vivo*. The filtrates have been prepared from centrifuged supernatants of infected, washed Ehrlich cells, homogenized in distilled water and filtered through sintered glass of porosity 5. For the transmission of infectivity *in vivo*, the starting filtrate was found to have unchanged potency up to a dilution of 1 : 100, with all-or-none tumour destruction occurring at higher dilutions. At 1 : 1,000, about 30 per cent of the tumours were destroyed, the remaining 70 per cent growing normally to a full yield. The potency of the final, 5th-passage filtrate was qualitatively unchanged, though it had undergone a dilution of the order of $1:5 \times 10^6$ during five serial transfers. Control filtrates from 'normal', isolated tumours (Ehrlich and Krebs), prepared in the same way, have never given rise to destruction of tumours or even modified the final yield of tumour cells as compared with untreated and saline controls.

Destruction of tumour cells begins after a latent period following infection. Transmissible infectivity has been extracted from washed cells throughout the latent period. Undiluted filtrates destroy the tumour cells after 3–5 days, but unfiltered extracts are more potent (titre of 10^{-7}), the first signs of cell damage occurring 15–20 hr. after infection. The Ehrlich and Krebs tumours are destroyed when treated with the virus at any stage of ascites growth. Destruction is quantitative in many cases when the agent is given shortly after the implantation of several million tumour cells. In many instances the ascites tumour is

effectively destroyed, but a solid tumour develops later at the site of implantation. The earliest result of infection is the sudden aggregation of tumour cells and the deposition of fibrin from the exudate which coagulates in the peritoneal cavity. Increasingly marked nuclear abnormalities leading to total nuclear disruption are seen during the ensuing three days.

The destruction of an established tumour results in the production of a substantial quantity of intraperitoneal debris, and adhesions are formed that give rise to intestinal obstruction, producing various degrees of illness. When a tumour implant is totally destroyed as a result of early treatment with the virus, little or no intraperitoneal disturbance occurs and the animals are indistinguishable from controls not bearing tumours.

A small group of normal mice without tumours, which received 10^6 times the tumour-destroying dose of a filtrate, have been observed for two months and have shown no sign of illness.

Infected cells taken during the phase of cell destruction have been examined under the electron microscope by Dr. R. Dourmashkin, through the courtesy of Dr. R. J. C. Harris, at the Imperial Cancer Research Fund Laboratories at Mill Hill. Large numbers of uniform particles, 75 mμ in diameter, have been found in the cytoplasm. Work is in progress to correlate the presence of these particles with the cytopathogenic effect. The appearance and other known properties of the agent suggest that it may be a new virus.

I thank Prof. Wilson Smith for his encouragement and advice during the latter part of this work.

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An Interferon-like Substance released from Tick-borne Encephalitis Virus-infected Chick Embryo Fibroblast Cells

An interference phenomenon between tick-borne encephalitis and Western equine encephalomyelitis viruses in chick embryo fibroblast monolayers has been described[1]. When chick embryo tissue cultures are inoculated with tick-borne encephalitis virus, the virus multiplies readily, but no cytopathic effect appears until the sixth or seventh day of cultivation. If cultures thus infected had been superinfected with a convenient dose of Western equine encephalomyelitis virus, which normally completely destroys the cells within 48–72 hr., the following events could be observed: (1) complete degeneration of cells caused by this virus and, hence, no interference if tick-borne encephalitis virus-infected cultures were challenged with Western equine encephalomyelitis immediately or 24 hr. after primary inoculation; (2) partial interference if cultures were challenged 48 hr. after inoculating them with tick-borne encephalitis virus; (3) complete suppression of the cytopathic effect caused by Western equine encephalomyelitis virus if challenged 72 hr. after primary inoculation. No interference was established if interfering virus previously neutralized by immune serum was added to cultures.

If, however, the culture fluid infected with tick-borne encephalitis was harvested and transferred to fresh non-infected chick embryo fibroblast monolayers, from which the original fluid had been removed, and immediately challenged with Western equine encephalomyelitis virus, no cytopathic effect caused by Western equine encephalomyelitis virus was present at the time of reading. Treatment of the transferred medium by immune γ-globulin against tick-borne encephalitis virus did not alter its ability to inhibit the cytopathic effect of Western equine encephalomyelitis virus. This phenomenon resembled interferon production in other cell-virus systems, first described by Isaacs and Lindenmann[2]. Results of some experiments analysing this observation are presented.

20 per cent mouse brain suspension of the *Hypr* strain (Czechoslovak tick-borne encephalitis) and the prototype strain of Western equine encephalomyelitis virus propagated in a chick embryo fibroblast bottle-culture were used throughout all experiments. Trypsinized chick embryo cells[3] were cultivated in a medium consisting of 5 per cent inactivated horse serum and 0·5 per cent lactalbumin hydrolysate in Hanks's solution with antibiotics and phenol red. Tube-cultures were seeded with 0·9 ml. of cell suspension containing 3×10^5 cells, 1,000-ml. Roux bottle-cultures with 3×10^7 cells in 50 ml. of medium. One-day old tube cultures were inoculated with 0·1 ml. of tick-borne encephalitis virus suspension diluted to contain 10^4 *LD*50, bottle-cultures with 0·5 ml. of virus suspension containing 10^3 *LD*50/0·1 ml. The culture fluid was harvested at various intervals, as given with the results. For testing the inhibiting activity of the media harvested, 1–3-day old tube-cultures were used. The Western equine encephalomyelitis virus used as challenge was diluted to contain 10^2–10^3 *TCD*50/0·1 ml. Results were read 3 days after adding the Western equine encephalomyelitis virus. Absence of cytopathic effect caused by Western equine encephalomyelitis virus was considered as positive inhibition.

Table 1 demonstrates the time of appearance of the inhibiting agent in tick-borne encephalitis virus-infected cultures.

For testing the ability of the agent to inhibit the plaque formation of Western equine encephalomyelitis virus a procedure adopted in this Institute for the screening of virus-inhibiting substances (Rada and

Table 1. Ability of Culture Fluids from Tick-borne Encephalitis (TE) Virus-Infected Cultures, harvested at Various Intervals after Inoculation, transferred to Fresh Non-infected Cultures, to inhibit the Cytopathic Effect of Western Equine Encephalomyelitis (WEE) Virus

Time of harvest after inoculation with TE virus	Ability to inhibit the cytopathic effect of WEE virus of untreated fluids			of fluids after contact with immune γ-globulin*		
	Undiluted	Diluted 1 : 10	Diluted 1 : 100	Undiluted	Diluted 1 : 10	Diluted 1 : 100
24 hr.	0	0	0	0	0	0
48 hr.	+	0	0	+	0	0
72 hr.	+	+	0	+	+	0
120 hr.	+	+	±	*NT*	*NT*	*NT*

* Each dilution of the fluid was mixed in the ratio 10 : 1 with a 1 per cent solution of immune horse γ-globulin against tick-borne encephalitis virus and incubated 90 min. at 37° C.

+, Positive inhibition (no signs of cytopathic effect); ±, partial inhibition (part of the cells degenerated); 0, no inhibition (all the cells degenerated); *NT*, not tested.

Tube cultures were challenged with 0·1 ml. suspension containing $3{\cdot}2 \times 10^3$ *TCD*50 of Western equine encephalomyelitis virus at the same time with the transfer of 0·9 ml. of each sample.

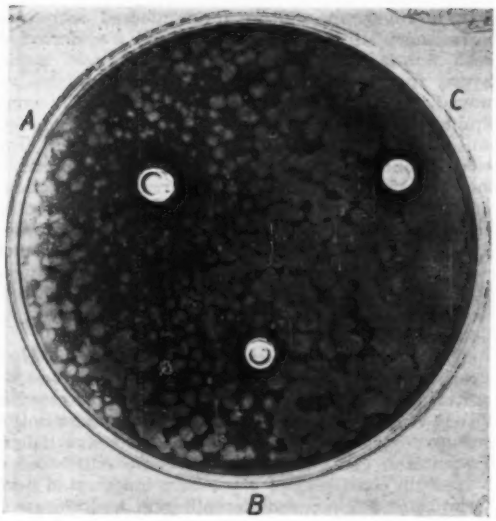

Fig. 1. Western equine encephalomyelitis virus plaque inhibition by the inhibiting agent placed in glass cylinders after adsorption of the virus. *A*, Undiluted fluid; *B*, fluid diluted 1 : 10; *C*, fluid diluted 1 : 100

Závada, personal communication) was used. After adsorption of Western equine encephalomyelitis virus diluted to contain about 5×10^2 plaque-forming units in 1·9 ml., chick embryo cell monolayers in 10-cm. Petri dishes were overlayed with agar into which small glass cylinders were placed. Two drops of the medium harvested from tick-borne encephalitis virus-infected cultures 72 hr. after inoculation and then treated with immune γ-globulin were placed in each cylinder, using the same dilutions as in the previous experiment. Otherwise the technique described by Dulbecco[3] was employed. Small but definite zones of plaque inhibition could be noticed around cylinders into which undiluted fluids were dropped (Fig. 1). A similar effect was noticed by Porterfield when testing interferon against a variety of plaque-producing viruses[4].

Some work on the mode of action of the agent is summarized in Table 2.

The same dilutions of the fluid which were effective in cultures, mixed with the same dilution of Western equine encephalomyelitis virus and immediately inoculated intracerebrally into mice, did not prevent death caused by Western equine encephalomyelitis virus; all the mice died within the normal incubation period of this virus (72 hr.).

Further evidence has shown that the virus-inhibiting agent released from tick-borne encephalitis virus-infected cells differs from the virus. The agent is adsorbed by cells in culture and seems to have no direct action on extracellular virus. It does not prevent death caused by Western equine encephalomyelitis virus in mice if tested by the same way as in cultures.

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Table 2. Studies on the Mode of Action of the Inhibiting Agent in Culture Fluid harvested from a Tick-borne Encephalitis (TE) Virus-infected Bottle-Culture 72 hr. After Inoculation

Group No.	Inhibiting fluid	Procedure used	Titre of transferred fluid*
1	Untreated medium†	WEE virus applied along with the transfer to cultures	1 : 80
2	Medium treated with immune γ-globulin‡	WEE virus applied along with the transfer to cultures	1 : 80
3	" "	WEE virus left to adsorb 1 hr. at 37° C., then fluid removed and inhibiting agent added	1 : 80
4	" "	Inhibiting agent left to adsorb 1 hr. at 37° C., then removed and WEE added	1 : 5
5	" "	Inhibiting agent left to adsorb 24 hr. at 37° C., then removed and WEE added	1 : 80
6	" "	Inhibiting agent mixed with WEE, incubated 1 hr. at 37° C., then transferred into cultures	1 : 80

* Highest dilution to which complete inhibition of the cytopathic effect was established with fluids transferred undiluted and twofold diluted from 1 : 5 to 1 : 160.

† Contained $10^{6.5}$ i.c. mouse *LD*50 of tick-borne encephalitis virus.

‡ Contained $10^{5.5}$ i.c. mouse *LD*50 of tick-borne encephalitis virus.

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Mode of Action of Micrococcal Phosphodiesterase

It was recently reported that phosphodiesterase isolated from *Micrococcus pyogenes* var. *aureus* hydrolyses tobacco mosaic virus nucleic acid giving rise to di- and mono-nucleotides[1,2]. On the basis of its action on this acid and synthetic polymers, polycytidylic acid and polyuridylic acid, it was postulated that the enzyme first cleaves the large nucleic acid molecule into several polynucleotides, which are further broken down by stepwise cleavage of mononucleoside 3′-phosphates starting from one end, until they are reduced to the size of dinucleotides, which are resistant to further action of the enzyme. Thus the enzyme appears to have both endo- and exo-actions. From the amounts of dinucleotides present in the final digest of tobacco mosaic virus nucleic acid, one can calculate the number of intramolecular breaks that are produced in the acid by the endo-action of the enzyme, by assuming that the dinucleotides are at one end of the resultant polynucleotide fragment. In these calculations the data used for the purine and pyrimidine composition of tobacco mosaic virus nucleic acid are those published earlier[2], and the molecular weight of nucleic acid was taken as 2×10^6 (ref. 4). From the calculations it appears that tobacco mosaic virus nucleic acid has been degraded to approximately 1,240 polynucleotide fragments, having an average weight of 1,600 or an average length of approximately 5 nucleotides.

However, the results presented earlier[2] do not show whether the polynucleotide fragments that are first formed as a result of the endo-action of the enzyme are further degraded starting from the 5′-hydroxyl end of the chain or from the 3′-phosphate end. Experimental evidence has now been obtained on this point, and as will be described, it appears that the enzyme degrades polynucleotide fragments from the 3′-phosphate end.

The polypurine nucleotide fragments, terminated by pyrimidine nucleotides used as substrate in the present work, were prepared as follows: 26·8 mgm.

tobacco mosaic virus nucleic acid, prepared according to the heat denaturation procedure[5], were dissolved in 2·5 ml. 0·02 *M* phosphate buffer at *p*H 7·6 and to this were added 1·5 mgm. of pancreatic ribonuclease (Worthington Biochemical Corporation, Freehold, New Jersey) in 0·5 ml. 0·02 *M* phosphate buffer at *p*H 7·6 and two drops of chloroform to prevent microbial growth. The mixture was incubated at room temperature for 18 hr. At the end of the reaction time, the digest was transferred to an ice bath, and to this was added with mixing cold 50 per cent trichloracetic acid. The final concentration of trichloracetic acid in the mixture was 6 per cent. This was held at 0° for 30 min. and centrifuged at 4° for 15 min. at 2,500 r.p.m. The precipitate was washed once with 0·2 ml. cold 6 per cent trichloracetic acid and this was followed by one washing with 0·4 ml. cold absolute alcohol. The washed precipitate was dissolved in 0·8 ml. 0·02 *M* borate buffer at *p*H 8·6. This was then transferred to a dialysis bag and dialysed against 0·02 *M* borate buffer at *p*H 8·6 for 6 hr. at 4° with continuous stirring. At the end of the dialysis time the volume was 0·9 ml. 0·05 ml. of the dialysed material when diluted to 25 ml. with distilled water gave an optical density of 0·176 at 258 mμ. The purine and pyrimidine composition[6] of this preparation was found to be as follows: adenine, 1·32; guanine, 1·00; cytosine, 0·17 and uracil, 0·25. This preparation is a heterogeneous mixture of several polynucleotides, rich in purines and poor in pyrimidines. Since these are obtained from the pancreatic ribonuclease digest it can be assumed that these fragments are terminated by cytidine 3′-phosphate and uridine 3′-phosphate. From the composition and the specificity of pancreatic ribonuclease it could be suggested that they average about seven nucleotides in length, six purine nucleotides terminated by a pyrimidine nucleotide $(Pup)_6Pyp$. This preparation was used as a substrate in the following experiment.

The reaction mixture, consisting of 0·7 ml. of the above preparation in 0·02 *M* borate buffer at *p*H 8·6, 0·05 ml. 0·1 *M* calcium chloride and 0·15 ml. micrococcal phosphodiesterase (3,000 units, a large excess to ensure complete digestion) and two drops of chloroform, was incubated at 37° for 18 hr. The digestion products were separated by paper electrophoresis at *p*H 3·5 and by paper chromatography in a solvent system containing 95 per cent ethanol and *M* ammonium acetate (75 : 30). The conditions used for the separation of the products and methods used for their identification were exactly the same as described earlier[2]. In the digest the following di- and mononucleotides were identified: adenylyl-(3′-5′)-adenosine 3′-phosphate (ApAp); adenylyl-(3′-5′)-guanosine 3′-phosphate (ApGp); guanylyl-(3′-5′)-adenosine 3′-phosphate (GpAp); guanylyl-(3′-5′)-guanosine 3′-phosphate (GpGp); guanosine 3′-phosphate (Gp); adenosine 3′-phosphate (Ap); uridine 3′-phosphate (Up) and cytidine 3′-phosphate (Cp).

Since the substrate used in this experiment is a heterogeneous mixture of polypurine nucleotides terminated by pyrimidine nucleotides (Fig. 1), the nature of the products that appear when digested with micrococcal phosphodiesterase depends upon the end from which the degradation of these fragments begins. In the reaction schemes I and II (Fig. 1) are shown the nature of the expected products.

If the degradation of these polypurine nucleotide fragments begins from the 3′-phosphate end, the products that accumulate in the digest are those

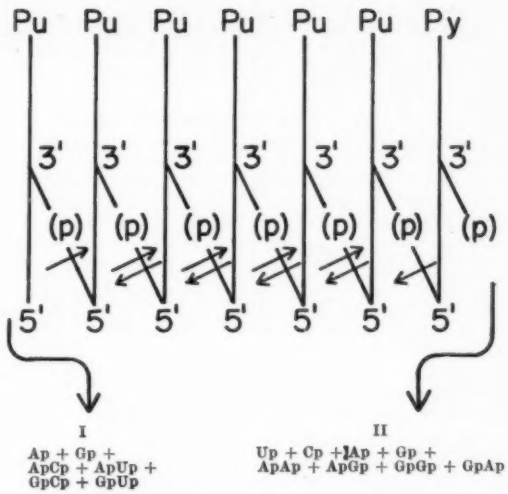

Fig. 1. *Pu*, Adenine, guanine; *py*, cytosine, uracil. ↗ indicates cleavage from 5′-hydroxyl end; ↙ indicates cleavage from 3′-phosphate end

given in reaction II. On the other hand, the products given in reaction I are found if the degradation is from the 5′-hydroxyl end of the chain. Since the products that are identified in the present experiment are the same as those in reaction II, it can be concluded that the micrococcal phosphodiesterase degrades the polynucleotide fragments beginning with the 3′-phosphate end.

In conclusion it can be stated that micrococcal phosphodiesterase has both endo- and exo-actions. It cleaves the large nucleic acid molecule into a number of small polynucleotide fragments and these are further broken down by stepwise cleavage of mononucleoside 3′-phosphates, beginning from the 3′-phosphate end, until they are reduced to the size of dinucleotides.

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A Difference between the Sub-Units of Tobacco Mosaic Virus Protein?

In an earlier investigation the protein fractions of two wild strains of tobacco mosaic virus and four mutation strains, which were derived from them, were compared analytically. In parallel with every mutational step small differences in the amino-acid composition could be demonstrated[1]. The virus preparations used in these investigations have been derived from inoculations steadily propagated during many years. Thus we should consider them genetic-

Table 1. Amino-Acid Content of the Proteins from Three Different Tobacco Mosaic Virus Strains propagated after several Local-Lesion Passages. Average Values ± Threefold Average Deviation from Mean calculated from Six Analyses (vulgare, flavum) and Three (necans)

Amino-acids	Moles per 100 moles TMV-protein*			Significant differences			
				vulgare – flavum		flavum – necans	
	vulgare	flavum	necans	P	Amino-acid per 17,000 m.w.	P	Amino-acid per 17,000 m.w.
Asp	11·70 ± 0·12	10·98 ± 0·09	11·01 ± 0·09	< 0·001	− 1·08		
Glu	9·71 ± 0·08	9·63 ± 0·13	9·54 ± 0·19				
Cys	0·57	0·60	0·63				
Ser	9·18 ± 0·17	9·24 ± 0·16	8·75 ± 1·00				
Thr	9·39 ± 0·12	9·61 ± 0·13	9·52 ± 0·29				
Gly	3·38 ± 0·05	3·30 ± 0·08	3·29 ± 0·15				
Ala	8·47 ± 0·11	8·95 ± 0·09	8·30 ± 0·23	< 0·001	+ 0·88	0·005	− 1·25
Pro	5·61 ± 0·09	5·60 ± 0·08	5·79 ± 0·32				
Val	8·82 ± 0·17	9·25 ± 0·34	9·62 ± 1·45	0·05	+ 0·89		
Leu	14·39 ± 0·45	13·71 ± 0·38	14·04 ± 1·56				
Phe	5·43 ± 0·09	5·71 ± 0·06	6·48 ± 0·17	0·005	+ 0·42	< 0·001	+ 1·06
Tyr	2·44 ± 0·29	2·24 ± 0·22	2·10 ± 0·74				
Lys	1·31 ± 0·12	1·34 ± 0·12	1·40 ± 0·46				
Arg	6·70 ± 0·20	6·84 ± 0·22	6·70 ± 0·49				

* Calculated using the coefficients of Levy (ref. 4).

ally to be populations, and perhaps as not uniform in the composition of their protein fractions. New material is now available from three of the earlier investigated strains: vulgare, flavum and necans. The new preparations have passed at least two single lesion inoculations before propagation. So they may be considered as uniform as experimentally possible. I used only preparations from plants with symptoms which are in good agreement with those earlier described[2,3]. The amino-acids of tobacco mosaic virus protein were estimated by Levy's technique[4].

The new analyses confirmed all differences in amino-acid composition already published[1]: parallel with the mutation vulgare → flavum the contents of aspartic acid, alanine and valine (?) are changed and with the mutational step flavum → necans one alanine was lost and one phenylalanine gained per peptide chain of a molecular weight 17,000. In addition a new significant difference in the phenylalanine content between vulgare and flavum has been found. It corresponds to 0·5 amino-acid residues per protein sub-unit (Table 1).

There are two possibilities to explain this finding: (1) At least one of the virus preparations consists of two or more strains of tobacco mosaic virus. (2) The protein sub-units of one strain already show some differences in the amino-acid sequence. In spite of the fact that the first assumption is improbable in regard to the precautions made, efforts were made to test it. The strains vulgare and flavum were inoculated on *Phacelia tanacetifolia* and *Phlox drummondii* instead of tobacco plants. If the inoculum consisted of a mixture of more than one strain, it should have eventually a different propagation-rate on the non-solanaceous plants and therefore the analytical difference in the phenylalanine content should be changed. This was not the case (Table 2). Therefore this variation in the phenylalanine content is regarded as an analytical demonstration of a difference in the composition of the protein sub-units in tobacco mosaic virus. (Of course there might be a corresponding difference of 0·5 amino-acid per molecular weight 17,000 in the content of another amino-acid also. But this happens perhaps to an amino-acid that exists already in quantity per protein sub-unit and therefore will not be established by recent techniques.) There is already some evidence for such small differences between the protein sub-units of tobacco mosaic virus. If about one lead atom per 17,000 molecular weight is fixed to the protein, equal amounts of lead are located at distances of 25 and 84 Å. from the axis of the particle, as was shown by X-ray diffraction studies[5]. Serological tests[6] suggested two different kinds of connexion between the sub-units of tobacco mosaic virus protein. The following two explanations seemed possible. (1) There exist two kinds of similar sub-units in one tobacco mosaic virus particle; (2) the sub-units are identical but arranged in pairs as mirror images.

Table 2. Phenylalanine Content of Two Tobacco Mosaic Virus Strains. Average Values ± Threefold Average Deviation from Mean, Each Calculated from Six Analyses of Preparations from Non-solanaceous Host Plants

Host plants	Moles per 100 moles protein		Significant differences vulgare − flavum	
	vulgare	flavum	P	Amino-acid per 17,000 m.w.
Phacelia	5·49 ± 0·13	5·82 ± 0·17	0·014	+0·49
Phlox	5·34 ± 0·06	5·64 ± 0·14	0·010	+0·46

I am indebted to Dr. M. Perutz, Cambridge, and to Dr. A. Klug, London, who demonstrated that the second assumption can be excluded by X-ray scattering. So the result of the serological investigation also points to a difference between the sub-units of one tobacco mosaic virus particle.

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RADIOBIOLOGY

Role of Initial Value of Metabolic Processes in Oxygen Consumption Changes in Rats during Irradiation

Changes in respiratory metabolism arising in rats during X-irradiation have shown that X-rays influence the course of metabolic processes during the period of exposure[1].

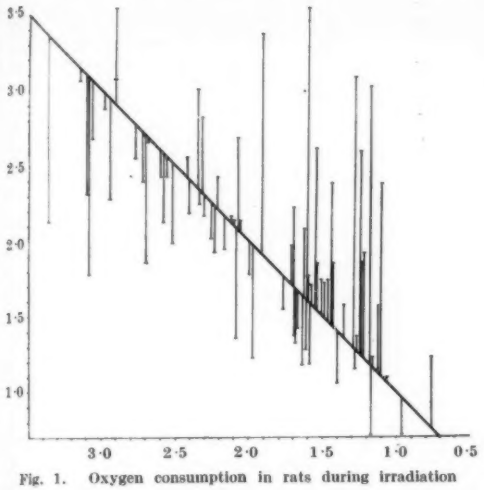

Fig. 1. Oxygen consumption in rats during irradiation

100 male rats (Wistar strain), average weight 190 gm., were divided into four experimental and one control groups, of 20 rats each. The rats were placed in the test chamber and the initial value of oxygen consumption in every rat was measured for 10 min., then the rats were put back in their cage. After a period of 45 min. the second estimation of oxygen consumption was made, and the rats were exposed to X-rays (180 kV., 15 m.amp., 1 mm. aluminium, 0·5 mm. copper, focal distance changed according to the dose-rate. Dose-rates were 100, 50, 20 and 10 r./min. Dose 1,000, 500, 200 and 100 r.).

The oxygen consumption of irradiated and control rats was measured individually by methods described in a previous paper[1].

I did not find any differences in average oxygen consumption in experimental groups during irradiation depending on the dose-rate; but I found that differences depend on the individual level of oxygen consumption before irradiation.

A comparison of oxygen consumption of experimental and control animals in dependence on the initial level of oxygen consumption is given in Figs. 1 and 2.

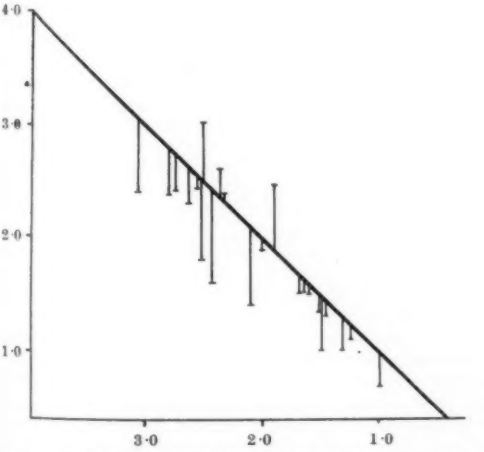

Fig. 2. Oxygen consumption in control rats. x and y axes, oxygen consumption (per cent); oblique line, the initial level of oxygen consumption; T, changes during irradiation

All experimental animals could be divided in three groups according to the value of initial consumption before irradiation: in the first group are animals with average values, in the second group are animals with extremely high values and in the third animals with an extremely low initial level of oxygen consumption. In the first group rats with an increased oxygen consumption and with a decreased oxygen consumption were observed, the average value of changes being at their initial level. In the second group, the rats have decreased their oxygen consumption and the average values of these changes are lower than their initial level. In the third group, the oxygen consumption is increased during irradiation and the average values are higher than their initial level.

The difference in oxygen consumption in groups of highest and lowest initial oxygen consumption during irradiation is statistically significant ($P = 0{\cdot}005$).

In the control group, I have not observed any changes in oxygen consumption during the second measurement when compared with their initial values.

I have not found in the literature any reports on the relation of the individual level of respiratory metabolism before X-irradiation to the changes in oxygen consumption during irradiation in the conditions described here. Other authors claim that initial oxygen consumption values in rabbits have the same importance for rabbits during daily periods after irradiation[2]. In my experiments, I have observed that rats irradiated under conditions used in radiobiological experiments changed their oxygen consumption during irradiation in a manner dependent on their initial value of oxygen consumption.

It has been shown[3] that irradiation has changed the vegetative balance, and I presume this may be important in connexion with the changes of oxygen consumption.

These results have shown that for work on the metabolic changes in rats during X-irradiation under the described conditions it is more important to know the initial oxygen consumption value of every experimental animal than the average value of the whole experimental group of animals.

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Metabolism of ^{14}C-Meso-inositol in the Rat

Although meso-inositol is widely distributed throughout Nature, little is known of its metabolic fate. Extensive investigations into the possible vitamin action of meso-inositol have been reported, but a clear dependence on exogenous inositol has only been shown for some micro-organisms and the cells of higher animals grown in tissue culture.

When a small quantity of substantially uniformly labelled ^{14}C-meso-inositol became available, through the courtesy of Radiochemicals, Amersham, it was thought desirable to investigate the fate of a trace-dose administered to the whole animal.

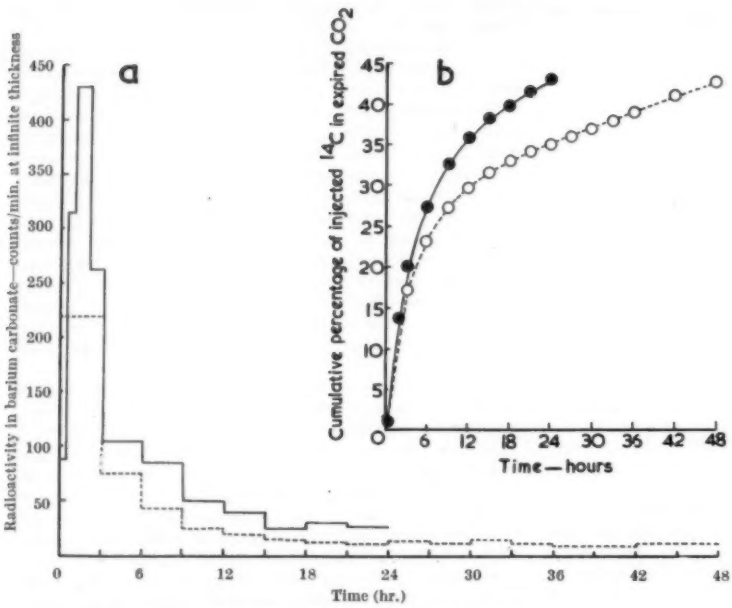

Fig. 1. Elimination of radioactive carbon of the injected inositol as expired carbon dioxide.
a, Radioactivity present in barium carbonate counted at infinite thickness and thus proportional to specific activity. – – – – –, rat *A*; ———, rat *B*.
b, Cumulative percentage of the injected ^{14}C-meso-inositol eliminated as carbon dioxide. ○ – – – – ○, rat *A*; ●———●, rat *B*

Two male albino rats of 356 gm. (*A*) and 223 gm. (*B*) were given respectively 10 and 9 μc. of the ^{14}C-meso-inositol intraperitoneally and immediately placed inside metabolism chambers containing food and water, and in which urine and faeces could be collected. The inspired air was freed of carbon dioxide, and the carbon dioxide in the expired air was collected by drawing the air through a series of absorption towers containing 5 *N* sodium hydroxide at a rate of 300 ml./min. The absorption train was emptied at intervals up to 48 hr. and 24 hr. in rats *A* and *B* respectively. Barium carbonate precipitates were prepared by the technique of Calvin, Heidelberger, Reid, Tolber and Yankwich[1], and the activity assessed, using a conventional thin-window Geiger–Müller tube, under the conditions of infinite thickness.

At the end of the experimental period the animals were killed and the free and total inositol determined on various tissues by microbiological assay[2]. Radioactivity, present in the tissues, was assessed after subjecting the extracts to chromatographic separation in butanol/acetic acid/water (4 : 1 : 5). The region occupied by the radioactive inositol was irrigated with water and the eluate absorbed on a standard disk of filter paper which, after drying in a vacuum desiccator, was assessed for radioactivity. The count-rates so obtained were corrected to values at infinite thinness by multiplying by a factor; determined by comparing the count-rate obtained from different concentrations of carbon-14 material at infinite thickness (absorbed on paper) and infinite thinness (thin film dried on a planchet).

In both rats the expired carbon dioxide obtained its highest radioactivity within the first 3 hr., and thereafter declined to reach an approximately constant rate of elimination 18 hr. after the injection (Fig. 1*a*). The decline in radioactivity in the carbon dioxide with time is approximately exponential and represents an average turnover of free inositol with a half-life of the order of 6 hr. However, the cumulative percentage of injected carbon-14 appearing in the expired air differed in the two rats. In rat *A*, approximately 42 per cent of the administered activity had been eliminated in the expired carbon dioxide 48 hr. after the injection, while in rat *B*, a similar elimination was achieved in 24 hr. (Fig. 1*b*). These figures should be increased by approximately 5 per cent to allow for some loss of carbon dioxide at the end of each collection period necessitated by the removal and replenishing of the absorbant. The discrepancy in the percentage eliminated in the two animals is difficult to ascribe to any definite cause. Similar observations of a rapid degradation of inositol to carbon dioxide have recently been reported by Moscatelli and Larner[3], under different experimental conditions.

The specific activity of inositol in the urine of rat *A* reached a maximum of 142×10^3 counts/min./mgm. inositol in the sample collected 9–15 hr. following the injection. In rat *B*, the specific activity in pooled urine samples obtained over the experimental period was $106{\cdot}4 \times 10^3$ counts/min./mgm. inositol. Total loss of radioactivity by renal excretion amounted to 0·33 and 0·58 per cent of the injected carbon-14 inositol in rats *A* and *B* respectively.

In rat *A*, the specific activity in the voided faeces was 107 counts/min./mgm. inositol, and the total loss of radioactivity by this route amounted to 0·014 per cent of the injected material, while in rat *B*, the specific activity was 155 counts/min./mgm. inositol and the total loss of radioactivity 0·024 per cent.

Blood samples taken from rat *B* under light ether anæsthesia by cardiac puncture 9, 16 and 24 hr. after the injection gave specific activities in the free inositol of 315×10^3, 50×10^3 and 26×10^3 counts/min./mgm. inositol respectively.

Table 1 shows the radioactivity present in the tissues examined. It will be seen that the specific activities in both the free and the combined inositol declined with time except in the case of the seminal vesicle. In the tissues examined in both rats, 10·6 and 4·0 per cent of the injected carbon-14 inositol were found at 24 and 48 hr. respectively. Most of this activity was present in the liver and kidney.

Examination of the carcass residue in rat *B*, after removal of the organs examined, indicated a radioactivity equivalent to 15·5 per cent of the injected carbon-14 inositol. The total activity recovered in this animal from the expired air, tissues, urine and carcass residue was approximately 70 per cent.

Although the radioactivity appeared to be confined solely to regions identified chromatographically as inositol on all chromatograms, it is possible that

Table 1. TISSUE AND SPECIFIC ACTIVITIES FUOND IN RATS KILLED 24 AND 48 HR. AFTER AN INTRAPERITONEAL INJECTION OF ^{14}C-MESO-INOSITOL

	Inositol fraction	Tissue activity (counts/min./gm. wet weight × 10^{-2})		Specific activity (counts/min./mgm. inositol × 10^{-5})	
		24 hr.	48 hr.	24 hr.	48 hr.
Brain	free	0·75	0·76	0·88	0·78
	combined	1·3	1·4	4·5	2·2
Heart	free	1·1	0·63	15·0	8·6
	combined	—	0·89	—	3·1
Liver	free	2·7	0·79	27·0	6·1
	combined	7·1	1·0	9·8	1·1
Kidney	free	32·0	14·0	40·0	34·0
	combined	6·1	—	27·0	—
Lung	free	2·4	2·3	14·0	9·0
	combined	5·3	—	11·0	—
Seminal vesicle plus secretion	free	34·0	2·7	8·8	0·56
	combined	2·0	2·7	0·76	4·7
Testis	total	1·2	0·31	0·42	0·49
Skin	free	—	0·04	—	0·50
	combined	—	0·76	—	5·4
Skeletal muscle	free	—	0·16	—	5·4
Bone	free	—	1·2	—	6·8
Sciatic nerve	total	—	0·18	—	0·15
Gut	total	—	1·6	—	2·9

components undergoing very rapid turnover in a large non-radioactive metabolic pool would have too few counts to be detected.

The relatively rapid degradation of inositol to carbon dioxide demonstrated in these experiments is of interest and is probably accounted for by the conversion of inositol to glucose. An interconversion involving D-glucuronic acid and the pentose phosphate pathway has recently been suggested by Burns, Trousof, Evans, Papadopoulos and Agranoff[4]. Of interest also is the high specific activity present in the kidney. Charalampous[5] has recently described a renal enzyme capable of converting inositol to glucuronic acid, while Richardson and Axelrod[6] have observed the overall degradation of inositol to carbon dioxide by rat kidney homogenates.

The results reported here suggest that in the rat at least there is an active participation of inositol in intermediate carbohydrate metabolism.

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BIOLOGY

Copper and Cobalt in Nitrogen Fixation

THE hæmoglobin found in the nodules of leguminous plants, first demonstrated by Kubo, has been since shown to vary in quantity with the condition of the nodules, and both Virtanen *et al.*[1] and Jordan and Garrard[2] have reported a relationship between the quantity of hæmoglobin present and the efficiency of fixation.

The role of hæmoglobin is at present not understood; but its presence implies the possibility that

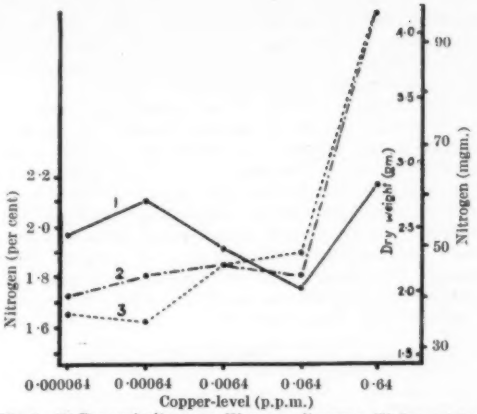

Fig. 1. (1) Per cent nitrogen; (2) mgm. nitrogen; (3) dry weight

copper and perhaps cobalt would be associated with its synthesis in the nodule. This is supported by the finding that vitamin B_{12} is present in the nodules, and that its concentration in the pink nodules of lucerne is four times as great as in white ones[3].

On this premise attempts have been made in this Department to investigate the effect of variation in the level of both copper and cobalt on the growth and ability to fix nitrogen of Mount Barker subterranean clover.

In the first case a comparison has been made of the growth in sand culture (after Hewitt[4]), using a modified Long Ashton nutrient medium containing 14 p.p.m. of nitrate nitrogen, on six levels of copper supply ranging from 0·000064 p.p.m. by tenfold steps to 6·4 p.p.m. The highest level was lethal, but the results of the other levels are given below.

As the yield and total nitrogen rose with increased copper supply, the percentage nitrogen fell from the low copper treatments to the Long Ashton level (0·064). Over this range the variation in nitrogen content appears to have been a function of yield only. Between 0·064 and 0·64 p.p.m. copper, however, there was a significant increase both in percentage nitrogen and in total nitrogen content.

Analogous results have now been obtained over three seasons with another strain (Bacchus Marsh), although the level of supply at which stimulation of nitrogen fixation occurred varied from one year to the next. We have not so far been able to demonstrate any change in the hæm content of the nodules between these levels of copper supply.

With cobalt, using the same technique as above, subterranean clover was planted out in the glasshouse on May 22, 1959, harvested 152 days later on October 21, 1959. The results for the plants receiving no added nitrogen are given in Table 1.

From this it is clear that although the highest concentration of cobalt used was restricting growth,

Table 1

	Dry weight (gm.)	Total nitrogen (mgm.)	Dry weight of nodules (gm.)
No added cobalt	5·543	154·7	0·407
0·0006 p.p.m.	5·420	154·9	0·526
0·006 p.p.m.	6·152	178·3	0·511
0·06 p.p.m.	6·365	189·3	0·341
0·6 p.p.m.	4·698	129·8	0·435

(Each seed contained about 0·41 mgm. nitrogen)

addition of cobalt at the rate of 0·006 and 0·06 p.p.m. had stimulated nitrogen fixation. (The effect on the growth of the plant was demonstrated to the British Society of Soil Science at a meeting at the School of Agriculture in September 1959.)

One consistent feature of our results has been that on the plants receiving added cobalt, the nodules increase in size relative to those not receiving this addition. This also holds even in those plants on a relatively high nitrate nitrogen supply (70 p.p.m.).

Our results show further that while the total hæm produced in the nodule is increased by addition of cobalt, its concentration per gm. of nodular tissue remains the same. This, however, is markedly depressed by increase in the nitrate nitrogen supply, as can be seen from Table 2.

Table 2

Nitrate nitrogen in nutrient medium	Cobalt added to nutrient medium (Hæm in μgm./gm. dry weight of nodules)				
	0	0·0006	0·006	0·06	0·6 p.p.m.
0	647	789	619	879	612
7	769	672	565	527	345
70	373	365	386	380	409

From the foregoing it would appear that there is a clear-cut effect of both copper and cobalt on the fixation of nitrogen by the legume–*Rhizobium* system. This would agree with what has already been demonstrated for *Nostoc*[5].

One other point of interest is that the addition of cobalt up to 0·06 p.p.m. showed in the early stages of growth a marked stimulation in the number of leaves produced, even when 7 p.p.m. of nitrate nitrogen was here supplied in the nutrient.

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Transmission of a Gall Disease of Cocoa

The disease of cocoa described as 'buba' or 'cushion gall' was first noticed in Colombia in 1938[1]. It was found afterwards in ten other countries in South and Central America[2] and also in Ceylon[3]. The disease causes hyperplasia and sterility of floral cushions, and is causing concern in areas of western Colombia, Nicaragua and Costa Rica where it has become widespread. Galls similar to those of the 'green-point' type in the western hemisphere have been known in Ghana since 1923[4] (Fig. 1). Following reports of the rapid spread of 'cushion gall' disease in Costa Rica investigations have been made in Ghana to assess the distribution and importance of the West African disease, and to find its cause. The purpose of this communication is to report the transmission of the West African disorder by methods which may be of immediate value to workers concerned with the American 'cushion gall' problem.

Fig. 1. Gall on mature tree. (× 2/9)

The disease has been transmitted from galls on mature trees, as well as those produced on artificially infected seedlings, by nymphs and adults of the mealybug species *Pseudococcus njalensis* Laing and *Ferrisiana virgata* Ckll. and also by various methods of mechanical inoculation. The first transmissions were made using the bean-feeding technique developed for use in the mealybug transmission of cocoa viruses[4]. Adults of *P. njalensis* from a naturally infested gall on a mature tree were transferred to 5 healthy cocoa half-beans at the rate of 10 insects per test bean. Three seedlings grown from these beans afterwards produced galls in the axil of the attached cotyledon (Fig. 2). In subsequent experiments, using insects from artificially colonized source galls, 18 out of 32 seedlings grown from test beans infested with *P. njalensis* and 12 of 15 infested with *F. virgata* produced galls. The disease has also been transmitted to test beans by rubbing and pricking them with macerated gall tissue and by the use of fine paint brushes first stroked over source galls or soaked in gall extracts. These methods gave a total of 47 transmissions in more than 300 bean tests, results from some of which are still incomplete.

The cause of the cushion gall disease in the western hemisphere is not known; but it has been suggested that virus-infections[6], eriophyid mites[7], a genetical abnormality, mineral deficiency or mineral toxicity, bacterial or fungal infections[8] may be involved.

Fig. 2. Gall on seedling. (× 2/9)

Transmission of the West African gall disease by mechanical methods in the absence of insects and other pests suggests that the disease has a pathogenic origin. Although fungal hyphæ have been observed in some stained sections of galls, only the ubiquitous *Botryodiplodia theobromae* Pat. and *Calonectria rigidiuscula* (Berk. and Br.) Sacc. have been isolated occasionally from gall-tissue. Grafting and insect transmission experiments have failed to demonstrate a systemic pathogen, and filtrates from seedling gall extracts passed through a Seitz filter (grade *EKS*, sterilizing asbestos film, Griffin and George, Ltd.) were non-infectious. Moreover, when young seedling-galls were macerated under sterile conditions in a small volume of water and centrifuged for 10 min. at 8,000 r.p.m. only the precipitate was infectious to beans. The results of these preliminary experiments indicate that the West African gall disease is of bacterial or fungal origin, although a virus cause cannot be completely ruled out.

Records from the survey[9], in which only 44 trees were found in a half-million acres of cocoa surveyed, show that the disease is at present of little economic importance in Ghana. However, because of the high infectivity of the West African disease in bean-transmission tests, and the similarity of its galls to those of the important 'cushion gall' disease in the western hemisphere, the disease is now considered to be of potential importance and the destruction of all galls on infected trees has been recommended.

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Effect of Glutathione and Alloxan on the Photoperiodic Response of *Xanthium*

It has been recently reported by Brachet[1] that a morphogenetic process in the alga *Acetabularia* is promoted by a substance containing —SS— and that the same process is inhibited by substances containing —SH. It appeared of interest, therefore, to test the morphogenetic responses of higher plants to substances containing thiol groups. For this purpose the effect of reduced glutathione on the process of floral induction in *Xanthium*, a short-day plant, was investigated. Alloxan, on the other hand, was chosen as an agent known to reduce rapidly the content of reduced glutathione of blood by both oxidation and coupling reactions[2,3].

Plants of *Xanthium pennsylvanicum* Wall. were grown from seeds, kindly supplied by Prof. K. C. Hamner of the University of California, Los Angeles. The general procedure followed that described by Salisbury[4]. On December 17, when six weeks old, 60 plants were defoliated to a single leaf (third from the apex), to the exclusion of any apical leaves exceeding 4 mm. in length. Immediately after defoliation, 50 plants were sprayed with an excessive amount of freshly made reduced glutathione solutions while 10 control plants were sprayed with distilled water. All sprays contained 0·1 per cent 'Tritone-*X*-100' spreader. The experimental plants were then subjected without delay to a single inductive 16-hr. dark period. An identical procedure was carried out the next day with alloxan. After 14 days the stage of floral development was determined applying Salisbury's system[5]. In addition measurements were made of the diameter of the growing point. The length of the largest leaf retained at the apex was adopted as a criterion of growth increment.

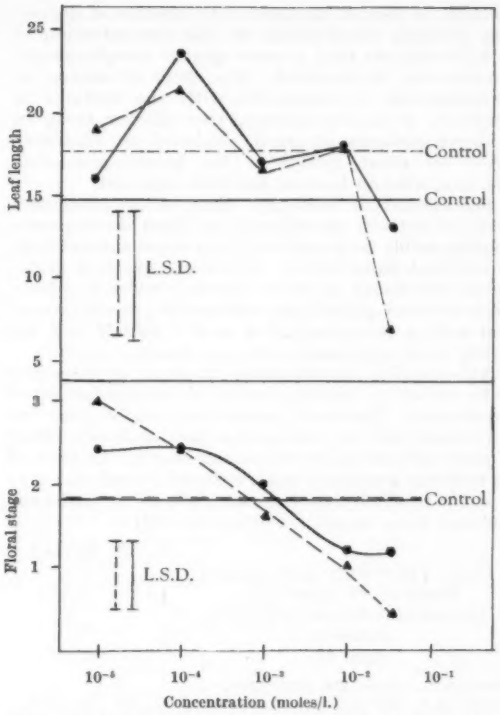

Fig. 1. Responses to different concentrations of reduced glutathione (●) and alloxan (▲)

The results show a promotive effect of both reduced glutathione and alloxan on floral development at low concentrations and an inhibitory effect in concentrations exceeding 10^{-3} *M*. A maximum effect of reduced glutathione appears to occur in the region of 10^{-5}–10^{-4} *M*, whereas in the case of alloxan the optimum concentration is possibly lower than 10^{-5} *M*. These trends were fully confirmed by the diameter measurements.

Both substances, when applied in low concentrations, exerted a promoting effect on apical leaf growth, with a pronounced maximum in 10^{-4} *M* for reduced glutathione. This substance at a concentration of $10^{-1.5}$ *M* caused a slight curling in the inductive leaf while the application of $10^{-1.5}$ *M* alloxan resulted in a partial necrosis of that leaf. Concentrations lower than $10^{-1.6}$ *M* did not produce any visible detrimental effects.

While it is very probable that the inhibitory effect of the high concentrations on morphogenesis is a

function of growth inhibition, the absence of depression of floral development at the concentration of 10^{-5} *M* suggests that a more specific morphogenetic process may be involved. The effect of alloxan on morphogenesis is consistent with the findings of Brachet[1]. It is not surprising that alloxan, being an oxidized analogue of uracil, produced an inhibitory effect on plant growth[6]. No growth-promoting effects of alloxan have so far been reported.

The absence of inhibitory effect of low concentrations of reduced glutathione on floral development might possibly be accounted for by rapid autoxidation to oxidized glutathione[7]. However, oxidized glutathione was found to have growth-inhibitory effect; while reduced glutathione resulted in growth promotion with a maximum at 3 to 6×10^{-4} *M* (ref. 8), which is in agreement with our results.

An excessive concentration of auxin is suspected to be one of the limiting factors in floral induction of *Xanthium*[5]. Reduced glutathione might play an important part by mitigating the inhibitory effect of superoptimal auxin concentrations[8,9]. In view of its multiple metabolic role[7], reduced glutathione may possibly produce morphogenetic effects by pathways different from simple donation of —SH.

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Xylan of Siphonaceous Green Algae

Comparatively little is known at present about the chemical nature of the cell wall constituents of siphonous green algae, especially that of the non-septate groups. Although the cell wall of the algae belonging to Bryopsidaceae, Caulerpaceae and Codiaceae has been stated to consist for the most part of callose (a name given originally to a polysaccharide-like substance of unknown chemical nature occurring in the callus plate of the sieve tube) and pectin and in *Bryopsis* and *Codium* in addition to some cellulose, no reliable characterization of these substances has thus far been made, their occurrence in the algal cell wall being inferred largely on the basis of staining reactions and solubility test[1]. Quite recently Mackie and Percival reported the presence of xylan in *Caulerpa filiformis* and established its structure as of β-1,3-linkage[2].

In the course of our work on the cell wall constituents of green algae we have found that each of the main cell walls of *Bryopsis maxima*, *Caulerpa anceps*, *Halimeda cuneata* and *Chlorodesmis formosana* consisted not of cellulose but of xylan, in which xylose residues are linked by a 1,3-bond. Besides these the presence of xylan also in *Udotea orientalis* and *Pseudodichotomosiphon constricta* was probable.

Of the materials used those of *Bryopsis*, *Caulerpa* and *Halimeda* were collected on the Pacific coasts not far from Tokyo and those of *Chlorodesmis*, *Udotea* and *Pseudodichotomosiphon* were obtained from Okinawa Island. Each of the air-dried algae was treated with 1 per cent hydrochloric acid at room temperature and then successively with 1·25 per cent sodium hydroxide and 1·25 per cent sulphuric acid at 100° for 1 hr. respectively. The residue was bleached with 1 per cent sodium chlorite, thoroughly washed with water and dried. Of the crude fibres thus obtained only that from *Bryopsis* gave weak but definite staining reactions for cellulose with iodine reagents, while with others the reactions were negative. None of these preparations showed optical anisotropy. On acid hydrolysis each crude fibre yielded crystalline D-xylose. Determination of xylan content by Tollens method gave the following results (per cent of moisture-free crude fibre): *Bryopsis*, 78·9; *Caulerpa*, 75·9; *Halimeda*, 78·0. From the crude fibre xylan was obtained by extraction with 10 per cent sodium hydroxide at room temperature followed by precipitation with ethanol. Purification was effected by repeating the ethanol precipitation of xylan from alkaline solution and finally by treating the product with hot water to remove soluble contaminants.

With these xylan preparations the following determinations were made, the results of which are given in Table 1.

When acted upon by sodium metaperiodate, the xylans consumed only a small amount of this oxidant as shown in Table 2.

The resistance of xylans towards periodate would indicate that xylopyranose as well as glucopyranose residues might be linked through C-1 and C-3. Assuming the 1,3-linked xylans to be of linear structure the oxidation by periodate will be restricted to the sugar residues situated at both ends of the chain, where per mole of xylan 3 moles of periodate will be reduced and 1 mole of formic acid produced. Based on the periodate consumption the degree of polymerization was calculated (Table 2), the values of which agree fairly well with those obtained by physical methods (Table 1). The 1,3-bonding of the xylans was also indicated by the production of intact

Table 1. Properties of Xylans

Source of xylan	C, H analysis calculated for $C_5H_8O_4$ C, 45·45 H, 6·06		$[\alpha]_D$ in 2·5 per cent NaOH	Glucose content (per cent)	Viscosity in *N* NaOH at 20·0° η_{sp}/c. (*c*., 0·045)	Molecular weight from	
						Sedimentation equilibrium	Viscosity*
Bryopsis	45·18	6·63	−38°	8·4	4·0	6,120 (46)†	5,500 (42)†
Caulerpa	45·96	6·03	−25°	9·1	4·4		
Halimeda	45·21	6·32	−26°	9·2	4·0		5,500 (42)†
Chlorodesmis	45·21	6·03	−31°	8·8	5·1		7,100 (54)†

* Calculated from η_{sp}/c. = km. M, where km. value for *Caulerpa*-xylan, $7{\cdot}2 \times 10^{-4}$, as obtained from sedimentation data was applied to other xylans.

† Degree of polymerization, calculated from sedimentation and viscosity data.

Table 2. Periodate Oxidation of Xylans

Source of xylan	Periodate consumed per xylose residue (mole)	Degree of polymerization, calculated from periodate consumption
Bryopsis	0·068	45
Caulerpa	0·063	48
Halimeda	0·068	45
Chlorodesmis	0·045	67

xylose and glucose as hydrolysis product of the periodate-treated xylans.

From *Udotea* as well as from *Pseudodichotomosiphon* of which the taxonomical position is still in dispute, crude fibres were obtained yielding a large amount of xylose on hydrolysis. Accordingly, these algae seem to contain a xylan of similar structure.

In some moulds belonging to *Aspergillus* and *Chaetomium* as well as in the hepatopancreas of certain molluscs the occurrence of enzymes was recognized which hydrolysed the xylans to xylose.

All these observations would indicate that the major constituent of these siphonaceous green algae, *Bryopsis*, *Caulerpa*, *Halimeda* and *Chlorodesmis*, and probably also that of *Udotea* and *Pseudodichotomosiphon*, is xylan with 1,3-linkage, which might correspond to so-called callose of these algae. Interesting in this respect is the observation that the 'callose' of *Codium*, unlike that of *Halimeda*, *Chlorodesmis* and *Udotea*, all of which are included usually in Codiaceae, is represented not by xylan but by mannan[3].

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Bacterial Effect and Radiophosphorus Assimilation in Organic and Inorganic Forms in Salmon

Approximately 90 per cent of phosphorus present in the body of a fish is found in the skeleton. The remaining 10 per cent is chiefly intracellular and plays a major part in energy-transfer mechanisms. The reservoir of phosphorus in the skeleton is also of great importance in maintaining adequate levels of this element in the tissues. Fish selectively absorb inorganic salts from water, and concentrate in various tissues the elements of which these salts are composed[1,2]. Furthermore, freshwater fish do not swallow water nor absorb salts through their skin but they carry on salt exchange only across the gills[3,4]. The present work was taken up to study the effect of bacteria and radiophosphorus assimilation in organic and inorganic forms in salmon, *Salmo salar* L.

By the courtesy of the Canadian Fish Cultural Development Branch, yearling salmon were brought from the Grand Lake rearing ponds and placed in a temperature-controlled room at $10 \pm 1°$ C., where they were given two days to settle down to the conditions of the laboratory. The experimental aquaria were in two sets, to one of which antibiotic tetracycline was added (0·1 gm. per litre) and left for 4 hr. so that the bacteria would be inactivated. Phosphorus-32 (Atomic Energy of Canada, Ltd.), in the form of phosphoric acid in diluted hydrochloric acid, was then added to both sets to give an activity of 2,100 counts per min. per ml. After 2 hr., fishes, which were roughly of the same size and weight (approximately 15 gm.), were put in both the sets. When phosphorus-32 was added to water in inorganic form a considerable portion is either ingested or transformed into organic form by bacteria and a condition of equilibrium is reached in about 24 hr.[5,6].

From each set, henceforth called control and treated (with antibiotic), four fishes were taken out at regular intervals and their tissues (liver, kidney, muscles, brain, heart and bone) were variously treated for counting the radioactivity. All the readings were corrected for decay and were standardized according to the uranium standard readings. When phosphorus-32 entered the body of the fish its distribution in the tissues was similar in both sets, bone taking up the maximum followed by liver, kidney, heart, muscles and brain. In the initial stages, up to about 24 hr., the uptake of radiophosphorus in both treated and control was almost similar. This can be explained by the fact that radiophosphorus in the control had not yet become completely equilibrated so that most of the radiophosphorus in both sets was in the inorganic form. After 24 hr., the uptake in treated set went up. In treated set, fishes could take up from water 39·6 per cent of phosphorus-32 and the control only 27·5 per cent. The turnover-time, which may be defined as the time required to renew completely the amount of substance present in the tissue, was calculated both for water as well as fish, and it came to 116·1 and 54·7 hr. in treated and 142·2 and 71·4 hr. in control respectively. These experiments indicate that fish absorbed more phosphorus-32 from the aquaria which had all the phosphorus in inorganic form. In the control, where three-fifths of phosphorus was transformed into organic form, the uptake was low.

The question which still remains to be answered is whether fishes can absorb phosphorus in organic form or not ? If so, what is the relationship between the two ? Another set of experiments was arranged to answer this question. Large quantities of phosphorus-32 were added to the aquaria and left for two weeks, after which the water was passed several times through a demineralizer until all the inorganic phosphorus was eliminated. Then it was passed through a millipore filter, which removed all the bacteria, and only phosphorus-32 in organic form was left in water. In other aquaria inorganic phosphorus-32 was put in water and tetracycline was immediately added to both the sets so that the activity of bacteria would be suppressed. In 144 hr., fish could absorb only 24·5 per cent of radiophosphorus in organic form, whereas in inorganic state they could utilize 43·0 per cent. The turnover time for water and fish came to 156·0 and 82·6 hr. for fishes maintained in organic phosphorus-32 and 107·5 and 51·8 hr. for fishes kept in inorganic phosphorus-32.

The conclusion arrived at is that fishes have a preference for, and absorb, inorganic salts more easily and rapidly than organic; but if they are forced to remain with salts in organic state, the assimilation will go on, but the rate of absorption and turnover is very much reduced. The detailed results will be published elsewhere.

My thanks are due to Prof. F. R. Hayes for his valuable suggestions and encouragement. Financial assistance in the shape of a post-doctorate fellowship from the National Research Council of Canada is gratefully acknowledged.

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ENTOMOLOGY

Use of Dieldrin in the Control of *Glossina palpalis* (R-D) in Nigeria

The control of *Glossina tachinoides* in the Northern Guinea Savannah Zone[1] of Northern Nigeria has now developed into almost a routine measure in which a single application of 5 per cent suspension of DDT wettable powder in water gives sufficient persistence to kill the young flies which emerge from their pupæ three or four weeks after spraying. In the Southern Guinea Savannah Zone, where the dry season is more humid and heavy dews form at night, even five applications at two-week intervals of DDT at concentrations varying between 2·5 per cent and 5 per cent have not proved very successful against a mixed population of *G. palpalis* and *G. tachinoides*[2]. In order to overcome this limited persistence it was decided to carry out a small trial using dieldrin, which was claimed to be more toxic and to have a longer persistence under these conditions.

The site of this trial lies towards the southern limit of the Southern Guinea Savannah Zone[1], where the vegetation is modified by extensive farming and broken up by many small river systems of which the majority contain flowing water throughout the year. These rivers support rain-forest type vegetation varying between 5 and 500 yards wide on either bank and typified by *Vitex cienkowski*, *Syzygium guineense*, *Uapaca* spp., *Phoenix reclinata*, *Khaya senegalensis*, *Adina microcephala*, *Sterculia* spp. and *Raphia* spp., forming a fairly continuous canopy with a dense thicket of bushes and creepers beneath. Along the rivers are to be found a reasonably high population of *G. palpalis* and a few *G. tachinoides*, and it is against both these species that control measures are aimed as both are vectors of *Trypanosoma gambiense*. 4·5 miles of river supporting heavy vegetation had previously been isolated from the other rivers by bush clearing as part of the existing tsetse control programme in the area. In addition the fly population had been studied for the three previous years as part of another experiment so that the behaviour and distribution of flies on this river were well known. No specific control river was used for the trial, but as another river about 10 miles to the south was being kept under observation this was considered to be a sufficient control.

To assess the fly population before spraying, twenty fly-catching points were chosen at nearly equal intervals along the length of the river. Four teams of two fly catchers each visited five points during a day, spending 1 hr. at each point, so that both rivers were completely inspected daily. The number of flies caught was recorded and the flies released at the end of each hour before moving on to the next point.

In contrast to the formulation used in the previous trial, where wettable powder was used, the spray was prepared from a water-miscible concentrate containing 20 per cent dieldrin and packed in 5 gal. drums. One part of this concentrate was added to four parts of river water, giving an emulsion containing 4 per cent dieldrin. The sprayers used were five 2-gal. 'Eclipse Warley' pneumatic sprayers.

It was found that a great advantage of using this preparation was that the concentrate could be added directly to water in the sprayers and therefore no bulk mixing or carrying of mixed solution was necessary. Spraying was concentrated mainly on all tree trunks and leaves up to 4 ft. from the ground throughout the width of the riverine vegetation, special attention being paid to fallen logs and the undersides of leaves overhanging the river-bed. Immediately after spraying the emulsion left a deposit from which the water phase evaporated after about 15 min., leaving the almost invisible oil phase. It was not until some 24 hr. later that a white deposit of crystals could be seen on the foliage. To eliminate the risk of spraying twice or of under-spraying due to being unable to see what had been sprayed before, a man with a matchet followed each sprayer and slashed trees that had been sprayed so that those following behind would know what had been already treated.

The effect of the insecticides on the fly population was immediate; the average daily total catch over all points for the week before spraying had been 31 *Glossina palpalis* per day (no *G. tachinoides* were present for the few weeks preceding the trial) and since early December 1957, when spraying took place, until December 1958, when fly rounds were discontinued, no flies were caught or seen on the river. This is in direct contrast to the results obtained using DDT, when a gradual fall-off in population was experienced. It has been noted previously in the Northern Guinea Savannah Zone, for example, in Katsina and Kano Provinces, where a single application of DDT is now used as a routine measure, that an absolute kill immediately following the application usually forecasts the success of the project. There was no significant drop in fly population on the control river.

In all, 52·5 gal. of water-miscible concentrate were used to treat the 4·5 miles of river, at a rate of 11·7 gal. of 20 per cent dieldrin per mile, the whole operation taking six working days to complete. The cost of spraying came to £41 per mile, which, in spite of the increased initial cost of dieldrin, compares very favourably with DDT, where the cost was £50 10*s*. per mile for five applications. Partial clearing by paid labour on this river would have cost between £100 and £200 per mile.

The use of dieldrin, if it is found in other cases to be as successful as the one just described, will represent a saving not only in the cost of the materials and transport, by needing only one application as

against four or five applications of DDT, but also in that a small spraying unit should be able to cover a length of river five times greater than would have been possible in the same time had DDT been used.

On the strength of the success of this trial a river system in the south comprising some 60 miles of river was treated with dieldrin as a field trial early in 1959 and the results so far are encouraging.

This communication is published with the permission of the Ministry of Health, Northern Nigeria, and the general administration and supervision of the fly rounds was carried out by Mr. J. Milton, sleeping sickness control officer.

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CYTOLOGY

Acetone Fixation for the Cytochemical Demonstration of Dehydrogenases in Blood and Bone Marrow Cells

The demonstration and localization of certain dehydrogenases within cells has been achieved cytochemically by exposing the cells to appropriate substrates upon which the dehydrogenases may act, in the presence of tetrazolium compounds capable of accepting hydrogen with the production of coloured insoluble pigments (formazans). The most satisfactory tetrazolium salt for this purpose is 'Nitro *B.T.*', a *p*-nitrophenyl substituted ditetrazole, which, under appropriate conditions, readily yields a finely granular formazan deposit[1,2].

The application of this technique to the study of blood and bone marrow cells has been hampered by problems of fixation, since fixatives giving adequate cell preservation generally inactivate the enzymes. Using air-dried smears of blood or bone marrow we have found this to be the case with most common fixatives, including methanol, ethanol, formalin solutions and formalin vapour. Attempts have been made to overcome the difficulty by allowing fresh suspensions of heparinized blood or marrow cells to react with the enzyme substrate and tetrazolium compound in test-tubes, smears then being made of the centrifuged deposit and afterwards fixed and counter-stained[3]. Unfortunately, considerable cell damage tends to occur during incubation and centrifugation, and accurate cell identification proves difficult to achieve.

There has recently been increasing interest in acetone as a fixative for enzyme cytochemical work, since it appears less inimical to enzyme activity than most other fixatives[4,5]. We have therefore carried out a series of experiments using different concentrations of acetone, alone or in various combinations with methanol, ethanol or formalin, at different temperatures and for different periods of time, as fixatives applied to air-dried smears of blood or bone marrow prior to incubation in the substrate–tetrazolium mixtures for cytochemical detection of succinic and lactic dehydrogenases. Mixtures of acetone with other fixatives generally gave excellent cell preservation, but invariably reduced enzyme activity, even when used for only 30 sec., whereas solutions of acetone alone allowed strong enzyme reactions to occur while providing, after an exposure of 30 sec.–1 min., a degree of fixation quite adequate for identification of cells and for enzyme localization at an intracellular level. The most satisfactory concentration of acetone was 60 per cent in distilled water, preferably used at room temperature, since ice-cold acetone solutions tended to wash off smears from the slides. Consistent and reproducible results were obtained with this method of fixation, and there appeared to be no decrease in enzyme activity in smears kept for 5–6 hr. before fixation. After this time dehydrogenase activity lessened, but was still detectable at 24 hr.

The full technique we have used for dehydrogenase cytochemistry in blood and marrow smears may be summarized as follows:

(1) Blood or marrow is smeared directly on glass slides and allowed to dry in air.

(2) Within 5–6 hr. the smears are treated with 60 per cent acetone in distilled water at room temperature for 30 sec.–1 min., rinsed in distilled water and air-dried.

(3) After fixation the smears are incubated for 1 hr. in the appropriate substrate, for example, for succinic dehydrogenase:

Phosphate buffer 0·2 *M* *p*H 7·4	10·0 ml.
Sodium succinate 0·2 *M*	10·0 ml.
Sodium bicarbonate 0·6 *M*	2·0 ml.
Calcium chloride 0·03 *M*	0·2 ml.
Aluminium chloride 0·03 *M*	0·2 ml.
'Nitro *B.T.*'	10 mgm. in 10 ml. of distilled water
Distilled water	to 40·0 ml.

(4) The smears are then rinsed with distilled water, dried and counterstained with 0·1 per cent nuclear fast red for 10 min.

Acetone not only provides a reasonable degree of fixation without inhibiting dehydrogenase activity, but also removes lipid particles on which the coloured formazan may otherwise be falsely localized. The pattern of positivity in leucocytes revealed by

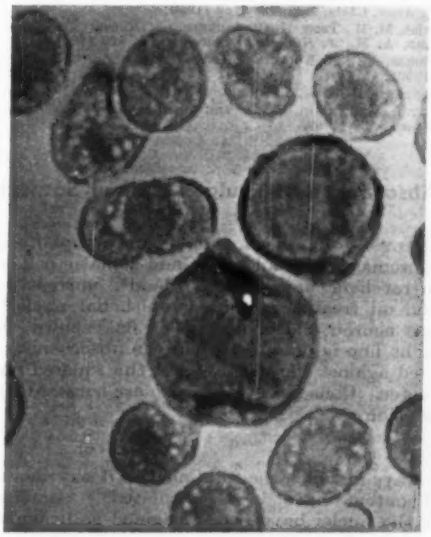

Fig. 1. Cytoplasmic positivity in lymphocytes. (× 2,000)

Fig. 2. Scattered granular positivity in leukæmic monocytes. (× 2,000)

staining with sudan black *B* is not, however, disturbed, since appearances after acetone fixation are similar to those after formalin fixation.

Patterns of succinic dehydrogenase distribution in lymphocytes and monocytes are shown in Figs. 1 and 2. Granulocyte precursors up to the stage of myelocytes and metamyelocytes also showed sites of enzymatic activity, but polymorphs were predominantly negative in the specimens we have studied hitherto.

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Absorbance of Feulgen-stained Somatic Cell Nuclei

Analysis of published data on cytophotometric measurements of Feulgen-stained somatic cell nuclei from rat liver and thyroid gland[1], untreated and croton oil treated mouse ear epithelial nuclei[2] and mouse neuron and liver nuclei[3] has shown that a straight line is obtained when the absorbance, E, is plotted against the reciprocal of the squared nuclear diameter. Consequently a and b are constants in the expression:

$$E = a + bD^{-2}$$

The ways in which the total nuclear deoxyribonucleic acid-content have been calculated[4-8] demonstrate that the nuclei have been imagined as being homogeneously absorbing objects, that is, objects in which the absorbing particles are randomly distributed, non-interacting and retaining their shape and number. But according to the equation the mass (=deoxyribonucleic acid-content) must remain constant, no synthesis can therefore take place, and this is contradictory to experimental facts. We can therefore conclude that in spite of the finding that the equation describes the data well, it does not mean that the nuclei are homogeneously absorbing objects. A non-random distribution of the Feulgen-stain was observed by DeSmul and LeComte[9], and reconstructions of serially cut human and rodent somatic nuclei in this laboratory[10] have shown that the Feulgen-stained material and the nucleoli are distributed in a peripheral zone. We can therefore conclude that the absorbing material, that is, deoxyribonucleic acid, is not randomly distributed and consequently that published data on the total nuclear deoxyribonucleic acid content, calculated from cytophotometric measurements of fixed tissue assuming a random distribution of the absorbing particles, are erroneous. The linear relationship between the nuclear absorbance and the inverse nuclear surface area may simply mean that both the absorbance and the geometrical dimensions are dependent variables of a common variable as, for example, the growth process, thus:

$$E = f_1(X) \text{ and } D^2 = f_2(X)$$

A practical consequence of this is, as is also evident from the equation, that a simple measurement of the nuclear geometrical dimensions will yield the same information as that obtained by the far more complicated and costly photometric method.

The numerical value of the constant b, which may well have different absolute values for different tissues, is thus not a direct measure of mass, but is a measure of the rate at which the absorbance decreases for unit surface area increase over a given mass range. For nuclei retaining their ploidy the growth process results in a doubling of the chromatin mass (deoxyribonucleic acid) and an increase in size between two consecutive divisions. As the relative mass of nuclei of different ploidy has the value of $1:2:4\ldots$, it follows that for a stationary population of nuclei of different ploidy the relative numerical values of the constant b will show this ratio. If transitions from one nuclear class to another occur the relative value of b will depend upon the intensity of transition. Deviations in the relative values of b from $1:2:4\ldots$ can accordingly be interpreted as a measure of the degree of cell differentiation. We would therefore expect, as also found by Moore[11], that the degree of deviation from the ratio of $1:2:4$ varies from individual to individual as well as with age.

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FORTHCOMING EVENTS

Tuesday, July 5

INSTITUTE OF PHYSICS (at 47 Belgrave Square, London, S.W.1), at 5 p.m.—Annual General Meeting.

Tuesday, July 5—Friday, July 8

FOURTH INTERNATIONAL GOITRE CONFERENCE (at Church House, Great Smith Street, Westminster, London, S.W.1).

Wednesday, July 6

BONE AND TOOTH SOCIETY (at 234 Great Portland Street, London, W.1), at 4 p.m.—Annual General Meeting, followed by Scientific Papers.

APPOINTMENTS VACANT

APPLICATIONS are invited for the following appointments on or before the dates mentioned:

ASSISTANT LECTURER or LECTURER (preferably with suitable qualifications in entomology) IN THE DEPARTMENT OF ZOOLOGY—The Registrar, The University, Liverpool, quoting Ref. CV/N (July 9).

JUNIOR LECTURER (with a medical degree and preferably a degree in physiology) IN PHYSIOLOGY—The Secretary, The Medical College of St. Bartholomew's Hospital, West Smithfield, London, E.C.1 (July 11).

RESEARCH ASSISTANT IN THE DEPARTMENT OF BOTANY, to carry out research with Dr. L. Fowden on nitrogen metabolism—The Secretary, University College, Gower Street, London, W.C.1 (July 11).

TEMPORARY LECTURER IN MEDICAL PHYSICS IN THE DEPARTMENT OF MEDICINE—The Registrar, The University, Manchester 13 (July 11).

BIOCHEMIST, Basic grade (preferably with previous experience in steroid work), to work in general clinical biochemistry, under the direction of the Consultant Biochemist—The Secretary, Edmonton Group Hospital Management Committee, North Middlesex Hospital, Silver Street, London, N.18 (July 12).

UNIVERSITY LECTURER IN THE DEPARTMENT OF APPLIED MATHEMATICS AND THEORETICAL PHYSICS—Dr. F. G. Friedlander, Secretary of the Appointments Committee of the Faculty of Mathematics, The Arts School, Bene't Street, Cambridge (July 13).

RESEARCH ASSISTANT (PHYSICIST) IN THE CERAMICS DIVISION of the Houldsworth School of Applied Science, to undertake an investigation of the influence of dissolved water on the physical properties of glass—The Registrar, The University, Leeds 2 (July 15).

CHEMIST, Assistant Experimental Officer or Experimental Officer grade, IN THE PEDOLOGY DEPARTMENT—The Secretary, Rothamsted Experimental Station, Harpenden, Herts (July 16).

LECTURER or ASSISTANT LECTURER (preferably with an interest in experimental study of molecular structure by diffraction techniques) IN INORGANIC OR PHYSICAL CHEMISTRY—The Registrar, University College of North Staffordshire, Keele, Staffs (July 16).

LECTURER or ASSISTANT LECTURER (with a special interest in inorganic chemistry) IN CHEMISTRY—The Secretary and Registrar, The University, Southampton (July 16).

LECTURER (with special competence in statistical and experimental methods) IN PSYCHOLOGY—The Secretary, The University, 36 North Bailey, Durham (July 16).

ASSISTANT LECTURER IN THE DEPARTMENT OF CHEMISTRY AND BIOCHEMISTRY—The Dean, St. Thomas's Hospital Medical School, London, S.E.1 (July 18).

DEMONSTRATOR (with an honours degree in chemistry or biochemistry, and prepared to engage in research in biochemistry with a view to obtaining a higher degree in this subject) IN THE DEPARTMENT OF CHEMISTRY AND BIOCHEMISTRY—The Dean, St. Thomas's Hospital Medical School, London, S.E.1 (July 18).

SENIOR LECTURER (with a first- or second-class honours degree in mathematics, and teaching experience in both pure and applied mathematics) IN MATHEMATICS at the Royal Naval College, Greenwich, London, S.E.—The Civil Service Commission, 17 North Audley Street, London, W.1, quoting Ref. 8/5154/60 (July 21).

SENIOR LECTURER (with a science degree specializing in geology, research experience in igneous and/or metamorphic petrology to Ph.D. or comparable level, an interest in field work, and preferably some overseas experience) IN GEOLOGY (PETROLOGIST) at the University of Queensland, Australia—The Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1, or The Registrar, University of Queensland, Brisbane, Queensland, (Australia and London, July 29).

SENIOR LECTURER and a LECTURER IN APPLIED MATHEMATICS at the University of Cape Town, South Africa—The Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1 (Cape Town and London, July 30).

PROFESSOR OF PHYSICAL CHEMISTRY at the University of Natal, Durban, South Africa—The Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1 (South Africa and London, July 31).

SENIOR LECTURER or LECTURER, to be responsible for courses in forest botany at graduate and postgraduate level; and a LECTURER (with research interests in either tree physiology and sylviculture or forest zoology) IN THE DEPARTMENT OF FORESTRY—The Secretary, The University, Aberdeen (July 31).

LECTURERS (qualified in some branch of applied thermodynamics or applied mechanics, including automatic control, or engineering materials) IN MECHANICAL ENGINEERING—The Secretary of University Court, The University, Glasgow (August 8).

METALLURGIST (with a science degree, preferably with honours or equivalent, and experience in metallurgical research) IN THE RESEARCH LABORATORIES, Australian Post Office, Melbourne, for research into the properties of metallic protective coatings, the investigation of metallurgical failures and the analysis of metals, etc.—Australian Post Office Representative, Australia House, Strand, London, W.C.2 (August 8).

SENIOR LECTURER (with medical qualifications or higher degrees in physiology) IN THE DEPARTMENT OF PHYSIOLOGY, University of the Witwatersrand, Johannesburg, South Africa—The Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1 (South Africa and London, August 15).

STATISTICIAN, Scientific Officer or Senior Scientific Officer grade (with a good honours degree and preferably postgraduate experience)—The Secretary, East Malling Research Station, near Maidstone, Kent (August 22).

LECTURER (with an honours degree in psychology, together with acceptable qualifications and practical experience in clinical psychology) IN PSYCHOLOGY at the University of Canterbury, Christchurch, New Zealand—The Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1 (New Zealand and London, August 31).

LECTURERS (2) IN GEOGRAPHY at the University of Melbourne, Australia—The Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1 (Australia and London, August 31).

SENIOR DEMONSTRATOR (graduate) IN ZOOLOGY at the University of Western Australia—The Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1 (Australia, August 31).

BASIC GRADE BIOCHEMIST (graduate in chemistry or biochemistry), to work in the Group Pathological Laboratory under the supervision of the Principal Biochemist—The Group Secretary, Reading and District Hospital Management Committee, 3 Craven Road, Reading.

BIOCHEMIST (NON-MEDICAL), for hospital biochemical work in the Mansfield Area Pathology Service—The Hospital Secretary, King's Mill Hospital, Sutton-in-Ashfield, Notts.

CHEMIST (with an honours degree in chemistry, some veterinary/agriculture or medical experience, and some experience in biochemistry) with the Government of Tanganyika, to supervise the Chemical Section of the Veterinary Research Laboratory, duties will include frequent safaris for experiments in the field—The Director of Recruitment, Colonial Office, London, S.W.1, quoting BCD.63/8/020.

CHIEF ELECTRONICS TECHNICIAN, to assist in the developments related to cardiac surgery—The Assistant Administrator, Radcliffe Infirmary, Oxford.

DEAN OF THE SCHOOL OF PHARMACY—Chairman of the School Council, School of Pharmacy (University of London), 29–39 Brunswick Square, London, W.C.1.

LECTURER (experienced graduate teacher with a knowledge of psychology) IN EDUCATION in the College (Training Department and School of Art)—The Warden, University of London, Goldsmiths' College, London, S.E.14.

LECTURER (qualified to teach physiology or comparative animal physiology to degree level) IN PHYSIOLOGY OR COMPARATIVE PHYSIOLOGY—The Registrar, Bradford Institute of Technology, Bradford 7.

LECTURER (single, male, preferably specializing in entomology and/or animal physiology) IN AGRICULTURAL ZOOLOGY and ASSISTANT WARDEN—The Clerk to the Governors, Essex Institute of Agriculture, Writtle, near Chelmsford, Essex.

LECTURER (well qualified physicist with research and/or industrial experience, and with, or prepared to develop, a strong interest in the physics of materials) IN PHYSICS—The Principal, Rugby College of Engineering Technology, Eastlands, Rugby.

POST-DOCTORAL FELLOW IN ORGANIC CHEMISTRY—Dr. R. A. Abramovitch, Chemistry Department, University of Saskatchewan, Saskatoon, Canada.

RESEARCH ASSISTANT (with a good honours degree in psychology, and preferably postgraduate training in psychology), to help in the investigation of intelligence and memory functions in normal and psychiatric elderly subjects at Bethlem Royal Hospital, Beckenham, Kent—The Secretary, The Institute of Psychiatry, The Maudsley Hospital, Denmark Hill, London, S.E.5, quoting Ref. R.F.94.

RESEARCH CHEMIST (graduate in chemistry with research experience), for analytical studies in soil and tissues—The Chairman, Dental Committee, Medical Research Council, P.O. Box 647, Dunedin, New Zealand.

SCIENTIFIC OFFICER (honours graduate in biology/zoology) IN THE BIOPHYSICS SECTION, for work relating to the physical–chemical basis of virus-antibody relationships and other aspects involving serological and biological assay—The Secretary, Research Institute (Animal Virus Diseases), Pirbright, Surrey.

SCIENTIFIC OFFICER (male or female, with an honours degree in science, pharmacy or biology), for duties which will consist of technical work in the Blood Transfusion Service Laboratories—The Director, Blood Transfusion Service, Roby Street, Manchester 1.

SCIENTIFIC OFFICER (with a first- or good second-class honours degree), to work in the Cardio/Thoracic Laboratories—The Secretary to the Board, The General Infirmary, Leeds 1).

SENIOR RESEARCH TECHNICIAN (with a knowledge of electronics and vacuum techniques, and preferably previous experience in electron microscopy), to assist in research projects of biological and medical significance—The Secretary, St. Bartholomew's Hospital Medical College, West Smithfield, London, E.C.1.

TECHNICIAN (preferably with some laboratory experience in cytology or histology) FOR CANCER RESEARCH LABORATORY—The Administrative Officer, Mount Vernon Hospital, Northwood, Middlesex.

TECHNICIAN (with experience in routine histology) AT THE ROYAL CANCER HOSPITAL, Chester Beatty Research Institute, Fulham Road, London—The Secretary, Institute of Cancer Research, 33 Sumner Place, London, S.W.7, quoting Ref. 301/B/32.

VISITING LECTURER (with previous experience in the teaching of philosophy at university level) IN PHILOSOPHY—The Chairman, Department of Philosophy, The University of Kansas, Lawrence, Kansas, U.S.A.

REPORTS and other PUBLICATIONS

(not included in the monthly Books Supplement)

Great Britain and Ireland

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